1.6 Civil/structural engineering personnel shall demonstrate a working level knowledge of applying the principles of force to stationary or moving objects.

Supporting Knowledge and/or Skills

a. Define the following:

- Force

Force is a vector quantity that generally produces a change in the state of rest or motion of a body. It produces an acceleration in the direction of its application. It is the direction and magnitude of the force that makes force a vector quantity. Newton’s second law of motion defines the concept of force as shown in the formula:

F = ma.

where:

“F” is the force on an object and can be measured in units called “Newtons” which are kilogram x meters/second^2 (kg*m/sec^2)

“m” is the mass of the object and can be measured in kilograms (Kg)

“a” is the acceleration of the object, which is the change in velocity over time; measurement of acceleration is similar to the measurement of velocity but with an accounting of the change over time; velocity is measured in distance and time as meters per second (m/sec) and acceleration is measured in meters per second per second (m/sec^2).

A force represents the action of one body on another. It may be exerted by actual contact or at a distance, as in the case of gravitational or magnetic forces. In other words, force is an external agency that is capable of changing a body’s state of rest or motion. A force can be characterized by its point of application, its magnitude, and its direction[i].

- Weight

Weight, also related to the concept of force, can be defined as the force of attraction of the earth on a given mass[ii]. Weight, therefore, is measured in units of force (e.g., newtons). Weight is considered a special application of force: it is defined as the force exerted on a body by the gravitational attraction of the earth. Weight can also be defined mathematically as:

W=mg

where:

"W" is the weight of an object and can be measured in terms of the mass (m) times the force of gravity (g). The force of gravity depends upon the elevation of the point considered as well as its latitude, since the earty is not truly spherical. The value of g therefore varies with the position of the point considered. As long as the point remains on or near the surface of the earth, it is suficiently accurate in most engineering computations to assume that g equals 9.81 m/s^2 or 32.2 ft/s^2.

Note that the <u>mass</u> of a body has the same value regardless of its location whether it is on the surface of the earth, above the surface of the earth, on the moon, or in space distant from any other body.

b. State the purpose of a free-body diagram.

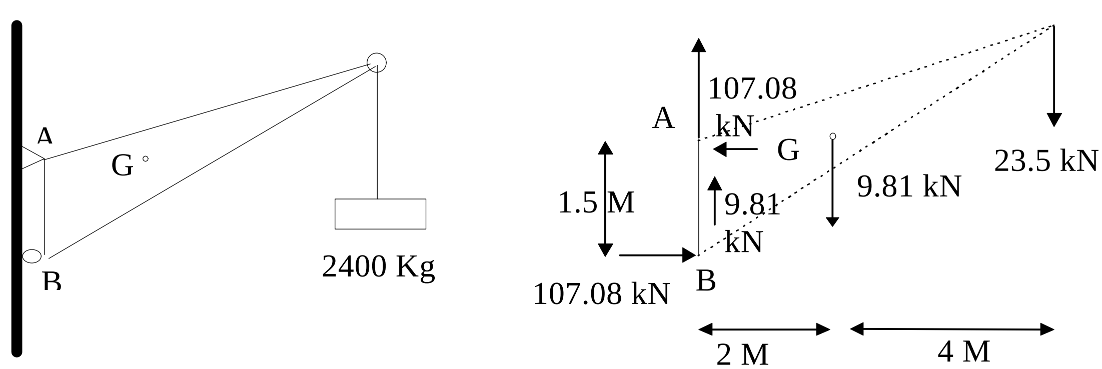
A free body diagram is a figure drawn to aid in the solution of a problem concerning equilibrium of a rigid body. In this diagram, all of the forces acting on the body are represented, whether they are known or unknown.[iii]

c. Given all necessary information, construct a free-body diagram.

Steps to be followed in constructing a free body diagram are as follows:

- Choose the free body to be used;
- Detatch this body from the ground and separate it from any other body;
- Sketch the contour of the body;
- Indicate all external forces, applying each at its point of action, such as where the body was supported by the ground or connected to the other bodies (weight should be applied at the center of gravity of the body);
- With each force, indicate the direction and magnitude of the force; and
- The diagram should also include dimensions of the free body which will be used in computatioin of moments of forces.

The diagram below is an example of a free body diagram of a crane.



Magnitudes of Forces:

$\sum M_B = 0 = 2(9.81) + 6(23.5) - A_H(1.5) \Rightarrow A_H = \dfrac{19.62 + 141}{1.5}$

$F_B = A_H = 107.\text{kN}$

$\sum F_Y = 0 = 23.5 + 9.81 = A_V \Rightarrow A_V = 33.31 \text{ kN}$

d. State the conditions necessary for a body to be in force equilibrium.

For a rigid body that is static (not moving), a body in force equilibrium:

- The resultant force vector must be zero (in each of the x, y, z axes); and
- The resultant moment vector must be zero (in each of the x, y, z axes) where Moment (M) = Force (F) x distance (d).

If the above conditions are not met, the body would be either deforming (not rigid) or accelerating (not static).

e. Define the following:

- Equations of condition

These are equations for either force or moment, applied at a point on the free body diagram, reduced to their three axial components for the chosen frame of reference. The sum of all of the force and/or moment equations for any given axis equals zero when the body is in equilibrium.

- Internal force

An internal force is a force that occurs within the structure or member that tends to deform the structure or member. Tensile and compressive forces (see below) are examples of internal forces.

In a free body problem, all indicated forces are <u>external</u> forces that act on the body. Since the free body assumes a rigid body, internal forces are not considered. Obviously, in the real world, bodies are not rigid and the structural integrity of any body is subject to the magnitude of the internal forces.

- Tensile force

Tensile force is the force defined as a force applied to a body that tends to pull the body apart. An example of tensile force is the force applied to a rope from a weight that is suspended by the rope. Tensile force is equal to the force exerted by the weight divided by the cross section area of the rope. Tensile strength is limited by the maximum tensile force that a material can support without deforming. Tensile force is described in terms of newtons per square meter or pounds per square inch.

- Compressive force

Compressive force, on the other hand, is an applied force that tends to compress the body to which it is applied. An example of a compressive force is the weight of an object that is supported by a rigid column such as the weight of a building that is supported by steel columns. The compressive force tends to compress the column. The compressive force equals the force applied to the column divided by the cross section area of the column. Compressive strength is limited by the maximum force that a body can withstand without deforming compressively.

- Net force

Net force is the sum of all of the forces (or moments) acting on a body. In any chosen axis, if the sum of the forces (or moments) is not zero, then the body is accelerating (or rotating) in response to the net force.

- Frictional force

Frictional force is that force which resists relative movement between two bodies in a direction parallel to the contact between the bodies. Frictional forces may be dry frictional force between dry surfaces or fluid frictional force between layers of fluid that are moving differentially.

- Axial force

Axial force is the force along a given axis in the chosen frame of reference. In equilibrium, the axial force (net) is zero for each axis.

- Shear force

Shear force is any force that is not axial, that is, it does not result in tension or compression. In a beam, the shear force is the component of a force vector that is perpendicular to the beam axis.

- Consistent joint forces

Consistent joint forces describes the situation whereby the forces at a joint in a structure sum to zero and the structure is at rest.

- Artificial joint forces

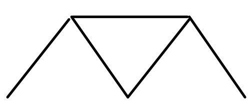
Artificial joint forces are an analysis tool used in the method of sections analysis (See Problem 1.12a) They exist only to indirectly determine sectioned member forces.

f. ***Define the following:***

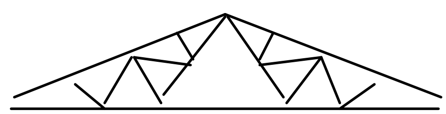
- Compound truss

A truss is a rigid structure with straight elements connected at their ends. Each element is a two force member which is slender and unable to support lateral loads, so all loads must be applied at the pinned joints. A simple truss is a truss that begins with three elements in a triangle, then adds elements in pairs attached to existing joints with a new connection at their free ends.

A truss which cannot be constructed from the basic triangular truss (not a simple truss) is a compound truss. See below.



Simple Truss



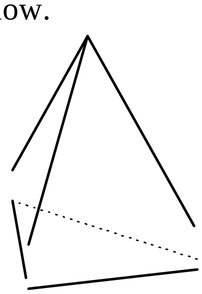
Compound Truss

- Complex truss

Complex trusses are those with inclined chords and multiple-web systems in which the method of sections may not produce a direct solution. If the truss is stable and statistically determinate, a solution can be obtained by applying the equations of equilibrium to a section taken aaround each joint. (A truss that has redundant members is considered statically indeterminate. See definition below.)

- Space truss

A three-dimensional truss in which several straight members are joined at their ends to form a rigid structure. A six-member truss which forms a tetrahedron is the simplest space truss. See below.



Space Truss

- Bending moment

Given a shear force (see above definition), a bending moment is the couple of the shear force and the distance component at which the force is acting.

- Deflection

Deflection is the displacement of a structural member when placed under load. Deflection analyses are used to determine the adequacy of the designed structural members. Standard American practice for buildings has been to limit service live-load deflections of steel beams to approximately 1/360 of the span length[ix].

- Side-sway

Side-sway is lateral movement of a structure caused by unsymmetrical loads or by an unsymmeyrical arrangement of building members.

- Cut-back structure

When there is a need to calculate the force in only one or a few members of a complex structure sectioned structure (or a cut-back structure) can be used. (Note: The term cut-back structure could not be located in any structural analysis text.)

For example, in analyzing a truss, a section through the truss can be taken that divides the member of interest. Each portion thus becomes a sub-truss and the forces in the severed members become external forces in the free body diagram. The force and moment equations then can be applied directly at the member of interest.

- Statically indeterminate structure

A statically indeterminate (redundant) structure is one for which the equations of statics are not sufficient to determine all reactions, moments, and internal force distributions. Additional formulas involving deflection relationships are required to completely determine these unknowns.

The degree of redundancy is the number of reactions or members that would have to be removed in order to make the structure statically determinant.

g. Explain the difference between a static-friction force and a kinetic-friction force.

A static-friction force is when there is no relative movement between the surfaces. Kinetic -friction (or dynamic-friction) force is when relative movement exists. Kinetic-friction forces are usually considerably less than static-friction forces for the same materials. It therefore takes less force to keep an object moving than it does to initiate movement.

For example, an object will sit at rest on an inclined plane when the force of gravity component (the component of the gravity force that is parallel to the surface of the plane) is not great enough to overcome the friction force. Once the object is given a momentary push to initiate movement, the object keeps moving and accelerating because the kinetic-friction force is now less than the force of gravity component.

h. State two factors that affect the magnitude of friction force.

Friction force is affected by the relative roughness of the surfaces that are in contact (referred to as the Coefficient of Friction) and the magnitude of the Normal Force (the force that is perpendicular to the surface of the object). On a horizontal surface, the normal force is the weight of the object. The Coefficient of Friction varies for different materials.

i. Explain the difference between centripetal force and centrifugal force.

Centripetal force is a real force directed inward toward the center or axis. Centrifugal force is an apparent force directed outward from the center or axis. Using the example of an object on the end of a string, being swung in a circle, the force that you apply by pulling on the string is centripetal, whereas, the force that the object applies to the string is centrifugal.

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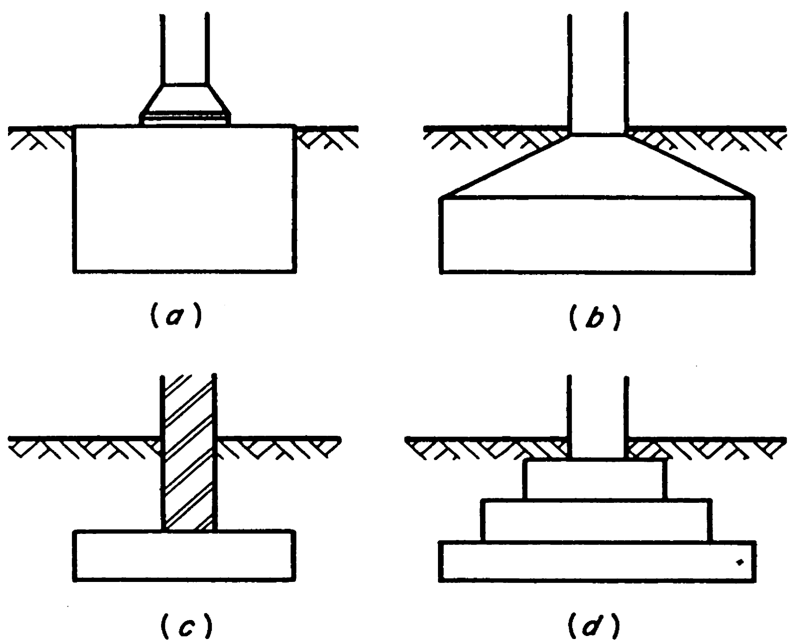
[i] Sears & Zemansky, *University Physics*, 3rd ed., Reading, MA., Addison-Wesley Publishing Co, Inc., 1964.
[ii] Uvarov & Isaacs, *Dictionary of Science*, 6th ed., Bungay, Suffolk, England: The Chaucer Press, Ltd., 1986.
[iii] Potter, *Principles and Practices of Civil Engineering*, 1st edition, published by Great Lakes Press, Inc., 1994.
[iv] McCormac, *Structural Steel Design: LRFD Method*, 2nd edition, published by HarperCollins, 1995.

1.7 Civil/structural engineering personnel shall demonstrate a working level knowledge of the basic principles and concepts of geotechnical science.

a. Identify and describe examples of shallow and deep foundations.[1,2]

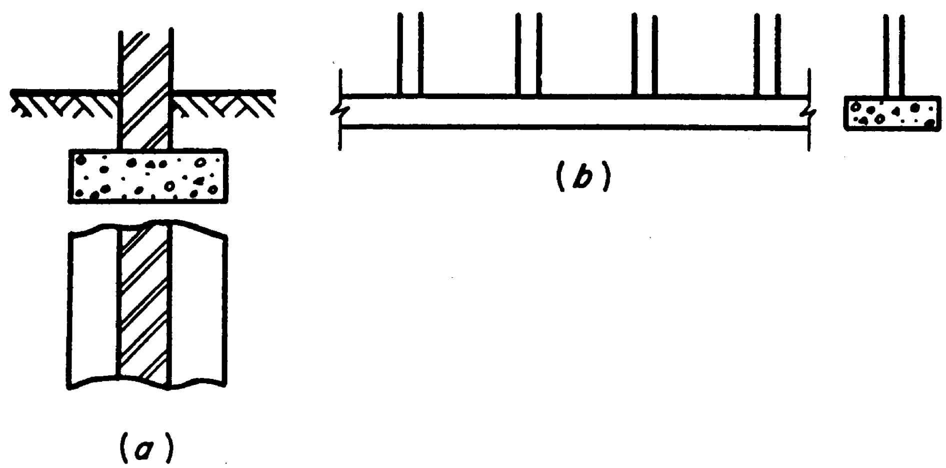
Shallow foundations are those where loads are transmitted to the soil at a depth adjacent to the lowest part of the functional structure. They are grouped into three major categories:

- <u>Pad foundations</u> Pad foundations typically provide support to structural columns. They may consist of a simple circular, square, or rectangular slab of uniform thickness, or they may be stepped or haunched to distribute the load from a heavy column.



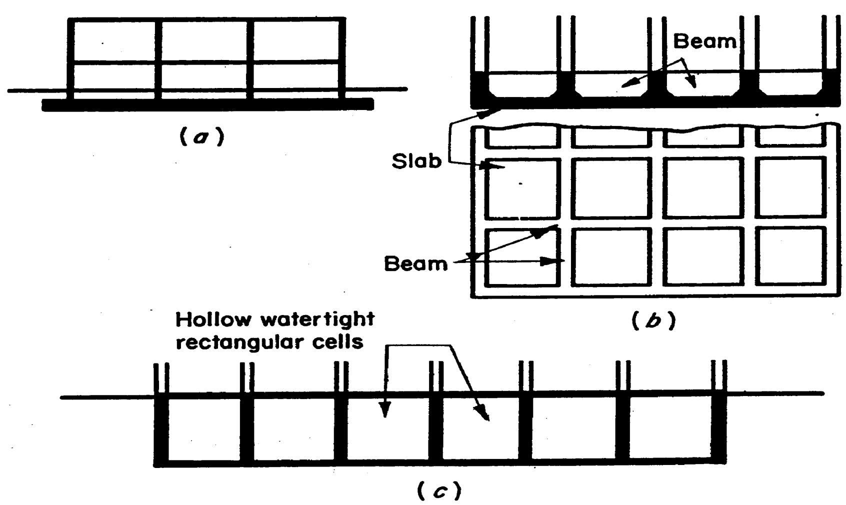
Types of pad foundation. (*a*) Mass concrete for steel column. (*b*) Reinforced concrete with sloping upper face. (*c*) Plain reinforced concrete. (*d*) Stepped reinforced concrete.

- Strip foundations. This type of foundation is normally used for load bearing walls and for rows of columns which are spaced so closely that pad foundations would nearly touch each other. This type of foundation typically consists of a strip of concrete which supports a load bearing wall or row of columns.



Types of strip foundation. (*a*) Strip foundation to load-bearing wall. (*b*) Strip foundation to a row of close-spaced columns.

- Raft foundations. This type of foundation is required on soils of low bearing capacity, or where structural columns are close in both directions that pads would touch or nearly touch. This type of foundation typically consists of a slab of concrete which supports a load bearing walls or rows of columns.



Types of raft foundation. (*a*) Plain slab. (*b*) Slab and beam. (*c*) Cellular (or buoyancy) raft.

Deep foundation are typically required where the soil at shallow foundation level cannot support ordinary pad, strip, or raft foundations or where structures have the potential to settle under their own weight because they are sited on deep fillings which are compressible. Deep foundations are grouped into two major categories:

- Bearing Piles. This type consists of long slender columns of wood, steel or concrete driven into the soil.

- Drilled Shafts, Piers, or Caissons. This type is typically concrete columns constructed in drill holes.

b. Discuss two basic elements of embankment design.[3,4]

Embankment design incorporates the following major steps:

- Extensive ground investigation to determine foundation and abutment conditions is the first step. Both compressibility of the foundation and embankment materials and shear strength of the foundation and abutment materials must be determined.

- The quality and quantity of available material in potential borrow areas must also be determined. Cost of excavation and transportation of the materials must be considered.

- Design of the embankment foundation is another step in the overall design of the embankment. Based on the analysis of the foundation material, several different approaches may be used. If the foundation is slightly compressible, then monitoring during construction to ensure the proper compression is occurring may be the only action necessary. If compression or shear is more of a potential problem, sand drainage may be provided to greatly accelerate compaction during construction. Finally, relocation or removal of the offensive materials may be required.

- The embankment itself may be designed as a homogenous unit or it may be designed in layers with alternate layers of good compacting material and good draining material. The economics of getting the material to the embankment is a major driver in the design. This will dictate what materials will be used and this in turn dictates the overall construction of the embankment. For example, a poor compacting soil will require a much wider base and more gentle slope than a good compacting soil.

c. Define erosion and describe the characteristics and effects of water and wind erosion.[3]

Erosion is the process of wind or water wearing away a particular substance.

- Water Erosion. Water erosion results in gullies which have three basic shapes based on the type of ground material. V-shaped gullies typically appear in rock or course textured sediments with fines that impart some cohesiveness. U-shaped gullies will form in materials which cave in easily such as silt or sand deposits. Finally, saucer shaped gullies are characteristic of cohesive materials containing considerable amounts of clay.

- Wind Erosion. Wind erosion results in the removal of thin sheets of material. This may result in wind scoured depressions, called blowouts. Wind can remove medium and fine sand or silt. Sand can typically only be carried a short distance by the wind while silt may be carried a long way.

d. Describe the types of tests used to determine the strength and dynamic properties of soils.[4]

Strength and dynamic property tests for soils fall into two basic types. Tests for determining the compaction characteristics of the soil and tests which determine the shear strength of soil.

- Compaction testing In general, these tests consist of compacting a number of soil layers with a rammer or vibrating hammer. The number of soil layers, weight of the rammer or vibrating hammer, and number of compacting blows or duration of the hammer test vary from test to test. These tests are performed several times at each set of conditions and then the conditions are varied. The independent variable is typically water content of the soil and the dependent variable is resulting dry density (the density of the soil if all water were removed). The results of dry density versus water content are plotted to obtain the optimum water content value. At low water content most soils tend to be stiff and difficult to compact. As water content increases, soil becomes more workable, facilitating compaction and resulting in higher dry densities up to the point of the optimum water content. As more water is added, the dry density lowers because the water is now a larger portion of the soil volume.

- Shear testing. These tests measure the shear strength of soils. One general test is the triaxial test. This test involves placing the specimen under axial load in a rubber sleeve. This results in equal all around pressure. The loading is increased until specimen failure occurs. The test can also be run with drainage from the specimen. The goal is to best simulate the field conditions of the soil in the applications which it will be used. Other shear tests have been designed specific materials such as clay or sand. These tests also determine at what point the material will fail under a given set of conditions.

- Dynamic properties are empiracally derived from both compaction tests and shear tests. Special equipment can be built in order to simulate special dynamic conditions on high priority structures for which no empirical data is available.

e. Describe the unified soil classification system. [4]

This system is a method for classification of soils. It consists of a two letter code as detailed below. The corresponding letter codes have a qualitative descriptor and a quantitative laboratory criteria.

Primary Letter	Secondary letter
G: Gravel	W: Well graded
S: Sand	P: Poorly graded
M: Silt	M: With non-plastic fines
C: Clay	C: With plastic fines
O: Organic Soil	L: Of low plasticity (w_L < 50)
Pt: Peat	H: Of high plasticity (w_L > 50)

f. Describe the following processes and explain how water and soil interact in each:

- Infiltration and percolation
- Groundwater recharge
- Runoff
- Moisture/density relationship
- Unsaturated flow
- Pore water pressure

The flow of water through the environment is known as the hydrologic cycle. The hydrologic cycle consists of evaporation, transpiration, condensation, precipitation, infiltration, percolation and runoff. Evaporation is the process of water being converted into water vapor and transpiration is the process of water being transported through a plants parts to be evaporated into the atmosphere (also known as evapotranspiration). Condensation is the formation of water droplets from water vapor. Precipitation is the deposition of condensed water vapor as dew, rain, snow, sleet, or hail. **Infiltration** is the movement of water into the soil. **Percolation** is the downward flow of water through soils and permeable rock layers into groundwater sources (this process is known as **groundwater recharge**). **Runoff** is the surface flow of water that does not infiltrate into the soil. Differences in energy with regard to free water as opposed to water in the soil as expressed per unit quantity of water is known as its potential. The downward flow of water through unsaturated soils is primarily due to its gravitational potential and constitutes **unsaturated flow**. Matric potential affects unsaturated soils and is the result of surface tension and adhesion of water to the surface of the soil. In addition, osmotic potential results form dissolved molecules and ions. Water usually moves from areas of high potential to areas of lower potential. However, water does not usually move from clay to sand -- even though the sand is drier, due to the higher adsorption properties of clay. In drier soils, water is more strongly held at lower potentials and is mainly restricted to narrow pores, resulting in the water flowing more slowly in unsaturated soils compared to the rate of flow through saturated soils.[5]

Moisture/density relationships in water and soil are calculated by dividing the weight of the soil and water contained within a sample by the weight of the dried soil from which the moisture has been expelled. This calculation gives the relative amount of moisture contained in the soil. Granular soils are relatively incompressible and water flows through these type soils largely without volume change. On the other hand, water movement through fine-grained materials in soil is generally associated with a volumetric change. Compressive forces on soil causes some volume decrease called consolidation. The volume loss occurs in the reduction of voids between the soil particles. If the pore voids are filled with a liquid, **pore water pressure** increases as the pore volume decreases assuming that liquid migration is restricted (as the case in fine-grained soils and clays). At some point hydraulic fracture of the soil occurs. Failure of the soil under these conditions can be manifest in collapsed foundation structures, land slides, and other features.[6]

g. Discuss the applicability of active, passive, and at-rest pressures to earth-retaining structures.

An at rest earth retaining wall structure describes a situation in the field where a retaining structure has not allowed the soil to move. Without movement of the soil, failure criterion do not apply to describe the state of stress. The soil structure can be described, however, by the effective stress of the soil factored by an experimentally determine constant, K_o. Thus, pressures on a earth retaining structure are a factor times the in situ state of stress.

When an earth retaining structure is installed, but not completely rigidly, and the soil is allowed to deform in the direction of the wall, this is called the active pressure state. The active state involves using gravity on the soil mass to contribute to the deformation. Thus, all retaining walls designed through this criteria must be strong enough to overcome the effects of gravity and prevent failure along a surface in the soil structure.

The passive state is just the opposite. Gravity, in this deformation situation, is contributing against the direction of strain. This situation is less frequent than the active state, but is a concern when using highly tensioned soil nails to pull the wall toward the soil mass. Because of the effects of gravity, the force required to fail a soil structure in the passive state is much, much higher than the force required in the active state.

h. Define the following:[1, 3, 4]

- **Vertical geostatic stress** – The force per unit area transmitted in a normal direction across a horizontal soil plane. This stress will be due to two factors the dry weight of the soil and the pore water pressure captured in the soil acting on the plane.

- **Horizontal geostatic stress** – The force per unit area transmitted in a normal direction across a vertical soil plane. This is the stress due to lateral expansion of the soil.

- **Bearing capacity** – The pressure that a soil is capable of carrying, (i.e. the pressure at which shear failure occurs.)

- **Soil compression** – The amount of volume change of a unit volume of soil undergoes when a unit increase in stress is applied to the soil.

- **Primary consolidation** – The gradual reduction of volume of a fully saturated soil of low permeability due to drainage of some of the pore water.

- **Secondary consolidation** – (Secondary Settlement) This occurs as the soil skeleton compresses under constant stress after all pore water has been drained from the soil.

- **Bearing piles** – Vertical or slightly inclined, relatively slender structural foundation member which transmit loads form the superstructure to competent soil layers.

- **Tension piles** – Piles which are designed to hold an object from rising. Typically, tension piles are used in water where a buoyant force may lift a structure.

- **Caisson** – A structure which is sunk through ground or water for the purpose of excavating and placing a foundation at a prescribed depth and which subsequently becomes an integral part of the permanent work.

i. Explain Darcy's Law of Permeability[4].

The volume of water flowing through a saturated soil will vary based on the porosity of the soil, the hydraulic gradient present, and the cross-sectional area where flow is taking place.

In one dimension volumetric flow rate can be calculated by the following equation:

$q = Aki$

Where:
- q = volume of water flowing per unit time
- A = cross-sectional area of soil corresponding to flow
- k = coefficient of permeability. This is based largely on the soil pore size and the distribution of particle sizes.
- i = hydraulic gradient

j. List the soil and site data required for a new structure[1].

- The site and soil following data is required for foundation engineering purposes:

  ◊ The general topography of the site as it affects foundation design and construction (e.g., surface configuration, adjacent property, the presence of watercourses, ponds, hedges, trees, rock outcrops, etc., and the available access for construction vehicles and plant.)
  ◊ The location of buried serves such as electric power and telephone cables, water mains, sewers and especially gas lines.
  ◊ The general geology of the area with particular reference to the main geological formations underlying the site and the possibility of subsidence from mineral extraction or other causes.
  ◊ The previous history and use of the site including information on any defects or failures of existing or former buildings attributable to foundation conditions.
  ◊ Any special features such as the possibility of earthquakes or climatic factors such as flooding, seasonal swelling and shrinkage, permafrost, or soil erosion.
  ◊ The availability and quality of materials such as concrete aggregates, building and road stone, and water for construction purposes.
  ◊ For maritime or river structures, information on normal spring and neap tide ranges, extreme high and low tidal ranges and river levels, seasonal river levels and discharges, velocity of tidal and river currents, and other hydrographic and meteorological data.
  ◊ A detailed record of the soil and rock strata and ground water conditions within the zones affected by foundation bearing pressures and construction operations, or of any deeper strata affecting the site conditions in any way.
  ◊ Results of laboratory tests on soil and rock samples appropriate to the particular foundation design or construction problems.
  ◊ Results of chemical analyses on soil or ground water to determine possible deleterious effects on foundation structures.

k. *Given soil properties and the applicable Terzaghi formulation, calculate the ultimate bearing capacity of a soil.*

Terzaghi's formulation was for a general shear failure in a shallow foundation. A shallow foundation is a foundation where the depth does not exceed the width. Terzaghi's formulation is good for strip foundations, circular footings or square footings. The equations for ultimate bearing capacity are:

Strip footing:

$$q_f = cN_c + p_o(N_q - 1) + g\frac{B}{2}N_g$$

Square or circular footing:

$$q_f = 1.3cN_c + p_o(N_q - 1) + 0.4gBN_g$$

Where:

q_f = ultimate bearing capacity
c = undrained cohesion of the soil
N_c, N_q, N_γ = bearing capacity factors obtained from charts in any soils reference
p_o = effective pressure of the overburden at foundation level
γ = density of the soil below foundation level
B = width of the foundation

l. *Given soil data, determine the factors that influence the soil volume and weight relationship.*[4]

Factors which influence soil volume and weight are the mass of solids, liquids (water) and air present in the soil and the volume of solids, liquids and air present in the same sample of soil. The following ratios are typical soil characteristics:

- water content (w) = water mass (M_w)/solids mass (M_s)
- degree of saturation (S_r) = volume of water (V_w)/volume of void space (V_v)
- void ration (e) = volume of voids (V_v)/volume of solids(V_s)
- porosity (n) = volume of voids (V_v)/total volume of soil (V)
- specific volume (v) = total volume of soil which contains unit volume of solids (1 + e)
- air content or air voids (A) = volume of air (V_a)/total volume of soil (V)
- bulk density (ρ) = total mass (M)/total volume (V)
- specific gravity of soil particles G_s
  = mass of solids (M_s)/(volume of solids (V_s) • density of water (ρ_w)
- particle density = mass of solids (M_s)/(volume of solids (V_s)
- unit weight (γ) = (total mass (M) • gravitational acceleration (g))/total volume (V)

Utilizing these ratios, soil volume and weight relationships can be determined.

[1] Tomlinson, M. J., *Foundation Design and Construction*, 5th ed., John Wiley & Sons, Inc., NY, 1991.
[2] Hsai-Yang Fang, *Foundation Engineering Handbook*, 2nd ed., Van Nostrand Reinhold, NY, 1991.
[3] Woods, Kenneth B., *Highway Engineering Handbook*, 1st ed., McGraw-Hill Book Company, Inc., NY, 1960.
[4] Craig, R. F., *Soil Mechanics*, 5th ed., Chapman and Hall, London, UK, 1992.
[5] Brady, N.C., 1974, The Nature and Properties of Soils, 8th ed, MacMillian Publishing Co. New York.
[6] Scott, R.F., J.J. Schoustra, 1968, Soil Mechanics and Engineering, McGraw-Hill, New York.

1.8 Civil/structural engineering personnel shall demonstrate a working level knowledge of the basic principles and concepts of hydrology.

Supporting Knowledge and/or Skills

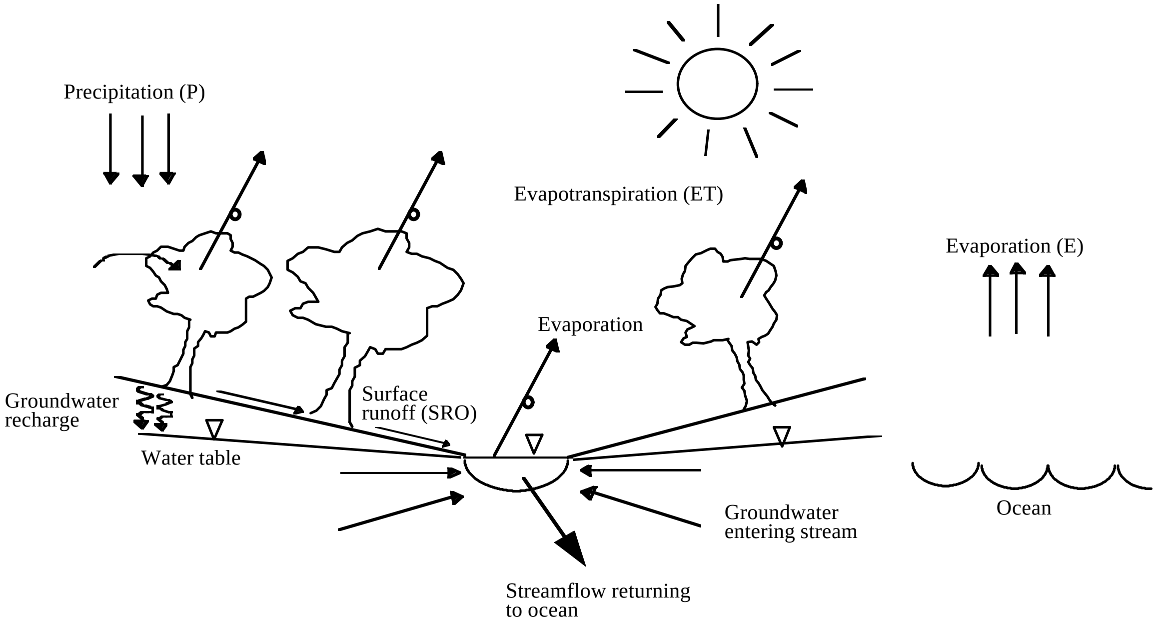
a. Define hydrology as it applies to civil engineering.

Hydrology is the study of the occurrence and distribution of water, both on and under the earth's surface. Through hydrologic analysis, engineers are able to quantify the flow of water under a variety of circumstances, allowing them to safely locate and design structures in or adjacent to waterways. Hydrologic analysis is also used to study water supply, design remedial environmental cleanup, and develop environmental protection measures.[1]

b. Describe the hydrologic cycle.

The hydrologic cycle is a continuous process without beginning. Rain or snow falls as precipitation, some is intercepted by plants and buildings, and never reaches the ground. Some infiltrates into the ground, and some runs off over the ground surface. A large portion of the infiltrated water is taken up by plants and evapotranspirated back into the atmosphere. The remainder enters the saturated groundwater and eventually flows back to the surface water system. Some of the runoff flows into depressions, where it either infiltrates to the groundwater, or evaporates into the atmosphere. A portion of the original precipitation runs off into the stream network. Water is evaporated from the oceans and lakes and delivered again through precipitation by weather systems (Figure 1.8-1).[2]

Figure 1.8-1



Hydrologic Cycle

c. ***Define the following hydrologic terms and describe the relationships between them:***

Precipitation is water droplets or ice particles that have condensed from atmospheric water vapor and are sufficiently massive to fall to the earth's surface as rain or snow. Several conditions must be met: (1) a humid air mass must be cooled to the dew point temperature, (2) condensation or freezing nuclei must be present, (3) droplets must coalesce to form raindrops, and (4) the raindrops must be of sufficient size when they leave the clouds to insure that they will not totally evaporate before they reach the ground.[2]

All surface and sub-surface water flows originate as precipitation. Evaporation and evapotranspiration return water vapor to the atmosphere to feed precipitation.

Stream flow is surface water which originated as runoff from precipitation or from groundwater sources and is moving down gradient. Most of this surface water either reaches the oceans, infiltrates into the groundwater, or evaporates. This part of the hydrologic cycle is the excess water which is not used by vegetation and/or cannot be retained as groundwater due to insufficient infiltration (runoff) or flows back to the surface as recharge to streams.

Evaporation is the conversion of liquid water into vapor, especially surface water into atmospheric water vapor. Water molecules are continually being exchanged between a liquid and atmospheric water vapor. When the amount of water passing into the vapor state exceeds the amount moving into the liquid state, evaporation results. Condensation is the opposite process and occurs when the air mass can no longer hold all of the water vapor that it contains.

Evaporation is the source term for the hydrologic cycle. Most of Earth's precipitation originates from evaporation of ocean surface waters. Transpiration (or evapotranspiration) is also like "evaporation" in that it is a method of returning surface water to the atmosphere, but in this case via living creatures.

Transpiration is the return of water to the atmosphere via living creatures.

In plants, transpiration is a product of photosynthesis as waste products are carried off through the stomata. Most of the vapor losses form a land-dominated drainage basin results from plant transpiration.[2] A much less significant source is from animals where the vapor is given off through the pores of the skin. Respiration is a similar process in animals that returns a small amount of water to the atmosphere. See evaporation, above, for effects on the hydrologic cycle.

Subsurface water (groundwater) is water that is below the earth's surface, which is a part of the saturated zone below the water table, especially that between saturated surface soils and rock layers.

The main source of groundwater is direct infiltration of precipitation and infiltration from collection depressions. This subsurface reservoir of water usually moves laterally (slowly) but sometimes is trapped in stagnant basins in low precipitation / runoff regions. Groundwater supplies wells and springs, and also recharges surface runoff directly.

Sediment is the material that settles to the bottom of a liquid. Sedimentation is the deposition of terrestrial materials that were transported either by air or water. Sedimentation is a byproduct of the hydrologic cycle where surface materials are transported to lake beds and ocean floors. Over geologic time, sediments have formed rock layers which determine the limits of groundwater movements due to their inherent permeability.

The **vadose zone** is that area which is below the earth's surface and above the groundwater layer (water table). It is considered the zone of aeration. The vadose zone is a three-phased system comprised of soil, water, and air. Water is in both the liquid and vapor phase. Smaller capillary pores may actually be saturated in the vadose zone.[2]

This zone is significant to hydrology and especially to the environmental sciences in that water must pass vertically through this zone before it moves laterally as groundwater. It is in this zone that migration of contaminants becomes a critical issue that determines the overall environmental impact.

The **saturated zone** is the groundwater area that lies below the aerated or vadose zone. The water table is at the top of the saturated zone. It is referred to as an aquifer. The saturated zone is the groundwater zone in which water and, therefore, contaminants, are transported laterally. This movement of groundwater is what allows groundwater to play a role in the hydrologic cycle. Wells tap into the saturated zone when it lies below the surface of the ground; springs produce stream flow or recharge surface waters where the saturated zone meets the surface.

Construction that penetrates into the saturated zone raises a host of requirements and building specifications, such as waterproofing, corrosion and erosion, etc. Lateral transport of environmental contaminants, and their reintroduction into the surface waters, is a major area of concern to the environmental scientist. Dense non-aqueous phase liquid (DNAPL) contaminates will pass vertically through groundwater and pool on an impermeable surface generally along the bottom of the aquifer. Their presence can only be detected from the generally low concentrations that will dissolve in the groundwater or from their presence in the vadose zone soils.

Attenuation is the reduction in amount or concentration (dilution) of a substance of interest, usually over distance.

Attenuation is important in civil engineering both as a design feature, where attenuation is designed into a system such as a sanitary waste treatment system, and as a environmental variable, where the substance of interest (contaminant) is migrating from some source term. The concentration of contaminants usually is reduced with distance from the source by the process of attenuation.

Dispersion is the movement in all directions of a substance of interest from the point of origin to a distant point, accompanied by a decrease in concentration. Dispersion of contaminants occurs in groundwater even if the groundwater is not itself moving. It is a process of natural mixing of the contaminant into the groundwater.

This process involves the usually unwanted movement of a substance (contaminant) by air, water, or some other natural agent. Dispersion unintentionally introduces the substance into areas which were not designed to contain or confine it, resulting a potential exposure of the ecosystem and/or population to the substance.

Permeability is the property or capacity of a porous material such as a rock, sediment, or soil to transmit a fluid; it is a measure of the relative ease of fluid flow under unequal pressure (head).

Highly permeable soils allow precipitation to quickly infiltrate to the water table. Low permeable soils restrict infiltration, causing increased runoff and slower recharge of the groundwater supply. A perched water table can occur locally where water is contained by soils of low permeability which lie above the water table. Artesian conditions can occur if an inclined soil layer of high permeability is confined by an overlying layer of low permeability. The pressure in the artesian layer is then governed not by the local water table but by a higher elevation water table at a distant location where the layer is not confined.

Porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices, whether the interstices are isolated or interconnected. Highly porous media in which the interstices are not interconnected will not transmit fluids while media with little porosity but with interconnected interstices will transmit fluids.

Conductivity is the rate of flow of water in gallons per day through a cross section of one square foot under a unit hydraulic gradient, at the prevailing temperature (gpd/ft2). In the International System, the units are m3/day/m2 or m/day. Hydraulic conductivity is governed by the size and shape of the pores, the effectiveness of the interconnection between the pores, and the physical properties of the fluid.[3]

d. ***Describe the flow of groundwater in the subsurface and discuss the importance of this to environmental restoration.***

As discussed in the definitions and relationships above, excess water (usually from precipitation) that infiltrates the soil and is not used by plant life migrates downward. The water passes essentially vertically through the vadose zone and ultimately reaches the water table. It may also get trapped temporarily in a perched water table. Once water has arrived at the water table, lateral movement down the hydraulic gradient occurs as does vertical mixing with existing groundwater in the aquifer. Groundwater may be thus transported great distances, over very long time periods. This water may be returned to the surface at varying distances from its point of infiltration by wells, springs, and direct recharge of surface waters.

If, in the process of moving from the surface to the groundwater aquifer, the water is contaminated by a hazardous substance, the moving water may become the transporting agent for the environmental contaminant. Vertical movement through the vadose zone creates one set of cleanup challenges; lateral movement in the aquifer crates a completely different set. Ultimately, the real risk to populations and ecosystems is when and if the hazardous substance is returned to the surface. Most cleanup technologies mitigate the risk of this reintroduction into the environment by removing the source of contamination and then by treating or isolating the impacted groundwater. The source of contamination may be located in the vadose zone or a non-aqueous phase liquid that is pooled on the water table or, if denser than water, within the groundwater.

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[1] Potter (section by D.A. Hamilton), *Principles and Practices of Civil Engineering, 1st edition*, Great Lakes Press, 1994.
[2] Fetter, C. W. Jr., 1980, *Applied Hydrogeology*, Charles E. Merrill Publishing Co. Columbus, OH.
[3] Driscoll, Fletcher G., 1986, *Groundwater and Wells*, Johnson Division, St. Paul, Minnesota.

1.9 Civil/structural engineering personnel shall demonstrate a working level knowledge of the basic principles and concepts of geology.

Supporting Knowledge and/or Skills

a. Discuss the following types of rocks, cite examples of each and how each one relates to water, vapor, or contaminant movement:

Igneous Rocks

Igneous rocks are formed by solidification from a molten or partially molten magma. A magma is a naturally occurring mobile rock material, generated within the earth and capable of intrusion into the upper crust of the earth or extrusion onto the surface of the earth. Magma consists of a liquid melt phase and a number of solid phases of suspended crystals of various minerals. In some cases, a gas phase also may be present.[1] Below the earth surface, intrusive igneous rocks form from the injection of magma into zones of weakness or from the heating and melting of older rocks that have become deeply buried. Intrusive igneous rocks are characterized by larger crystals that have formed from the slow cooling and resulting slow crystallization process. Examples are granite, quartz monzonite, diorite, and gabbro. Extrusive igneous rocks are formed from magma that has been released in the liquid state to the earth surface typically by volcanic eruption. Extrusive igneous rocks are characterized by relatively small crystals that are formed by rapid cooling permitted at the earth surface. Examples are andesite, basalt, and pumice. In some cases, the cooling process is so rapid that no crystals form and the resulting amorphous material is called obsidian.

Composition

The chemical makeup of the magma determines the mineralogical makeup of the igneous rocks that are derived from it. As a consequence of original cooling of the earth, chemical and mineral differentiation within the crust occurred. The differentiation process was largely driven by the temperature at which various minerals crystallize and the density of those minerals. The differentiation process resulted in heavier rocks forming the deeper, oceanic crust and lighter rocks forming the relatively shallow, continental crust. As a result igneous activity associated with oceanic crust is more typically associated with the formation of darker colored rocks that are composed of dense minerals. Typical of such rocks are those found in the lava flows of Hawaii. Basalt is typical of the igneous rocks that are associated with oceanic crust. The igneous activity associated with continental crust is more typically associated with rocks that are composed of less dense minerals. Granite is typical of the igneous rocks that form in the continental crust. Extrusive and intrusive igneous rocks form from both oceanic and continental magmas.

Identification

Igneous rocks are identified by the types of minerals present. Igneous minerals are those that formed from a molten magma. Not all minerals can be formed by the process of solidification from the molten state. The texture of the rock is an important means of identification. Igneous rocks tend to have very little visible porosity. The solidification process that results in the formation of the igneous rock causes the crystallizing minerals to grow together in a solid mass. Some types of minerals have a great propensity to form well defined mineral shapes and other minerals with less of this propensity fill intercrystalline spaces without developing well defined crystal faces. However, those magmas that contain a gas phase may result in the formation of highly porous igneous rocks. These rocks usually have very small crystals and a jagged appearance due to the rapidity and violent nature of their formation. Pumice is an example of a porous igneous rock.

Igneous rocks tend to be harder than other types of rocks. The minerals from which igneous rocks are formed are typically hard and this hardness is conveyed to the rock. Intrusive igneous rocks tend to form in large irregular blocks often in the uplands of mountain ranges. Therefore, the lack of appearance of tabular bedding associated with sedimentary rocks may indicate igneous rocks. However, some intrusive igneous rocks may have been injected between layers of sedimentary rocks and, subsequently, have the same layered occurrence as the rocks around them. Extrusive igneous rocks may also have a layered appearance if they were extruded on a reasonably flat surface.

Properties

Igneous rocks have a wide variety of properties because of the difference in the magma from which they formed, from the method of their formation, and from the effects of weathering after formation. Igneous rocks are usually not good aquifers because they have very little porosity. However, they can transmit water very efficiently if they are highly fractured. In such cases they may serve as a conduit through which groundwater can move from a source or recharge area to a discharge area.

Sedimentary Rocks

Sedimentary rocks are formed by the lithification of sediments usually in layers under relatively low temperature and pressure at or near the earth surface. Sedimentary rocks may also form from the precipitation of minerals such as calcite from a sea water brine.

Sediments are derived by the processes of weathering of other rocks and are transported to other areas by the action of wind, water, ice, and gravity. Sediments, once transported, are deposited as loose materials, generally in layers, that may eventually become solidified. Most sedimentary deposits are associated with the action of water. Slow-flowing or standing water will deposit sediments that have been carried by faster moving water. Where conditions are favorable for deposition, layers or strata gradually accumulate. As accumulations thicken, pressure from above compacts the underlying sediments and squeezes out much of the water contained in the sediments. Inter-granular chemical reactions and reactions with the dissolved constituents in the water results in cementation of the sediment particles into a lithified mass or sedimentary rock.

Sandstone and conglomerate are examples of sedimentary rocks that are formed from sand and gravel deposits. Shale is the sedimentary rock that forms from clay deposits. Limestone and dolomite are the typical sedimentary rocks that form from the precipitation of minerals from a sea water brine.

Composition

The composition of sedimentary rocks vary considerably. This is due to the variability in the sources of the sediments and the weathering impacts on those sources. Sediments may consist of various sizes, mineral compositions including organic compounds, and have a variety of physical properties.

Sandstone and conglomerate are two typical types of sedimentary rocks. They are characterized by particles of sand and gravel that have been lithified. The sand and gravel particles usually have a high quartz content but can contain a variety of other minerals most typically feldspar. Shale is another type of sedimentary rock. It forms from the compaction of clay particles. Clay is formed from chemical reactions resulting from the weathering of minerals found in igneous and metamorphic rocks. Limestone and dolomite are sedimentary rocks that form from chemical precipitation from sea water brines. Limestones can also contain large amounts of shells from marine animals.

Identification

Sedimentary rocks are identified by typical layered character that results from the method of sedimentary deposition. Sedimentary rocks can usually be found in relatively thin but laterally extensive strata. These strata are usually layered to form thick sequences of rock that reflect a variety of successive environments of deposition.

Unlike igneous rocks, sedimentary rocks usually result from processes that tend to weather away less chemically and physically stable minerals. As a consequence sedimentary rocks usually consist of only a limited number of very stable minerals.

Some sedimentary rocks contain fossils. The appearance of fossils is an almost absolute indication of sedimentary origin. Igneous and metamorphic processes so completely change source materials that fossils are not preserved.

Properties

Sedimentary rocks are the softest and most pliable of the rock types. Sediments are held together less firmly than the minerals in igneous and metamorphic rocks. Even though sediments such as quartz can be very hard, the rigidity of sedimentary rocks is reduced because of the cementation that holds the sediments together. Shale can be very soft because it is composed of clay.

Sandstone, conglomerate, and some limestones can be highly porous and may be very good aquifers. These rocks can also be highly fractured or in the case of limestone can contain caverns that will transmit water very rapidly. Shale is usually very impermeable and typically forms good aquitards or barriers to ground-water flow. However, hard highly lithified shale may be extensively fractured and, thereby, becomes a good transmitter of water.

Metamorphic Rocks

Metamorphic rocks are rocks that have had their original form altered by one or more geological processes (such as heat, pressure, and chemical action). Due to alteration, the rock is changed (metamorphosed) into a rock with different texture, structure, mineral composition, or general appearance. The original chemical composition of the rock, however, remains unchanged through the alteration process because there is usually no movement of materials in or out of the altered rock mass. High grade metamorphism is due to intense heat and pressures deep beneath the earth surface. Most high grade metamorphic rocks are exposed at the surface by mountain building (tectonic) activity.

All types of rock (igneous, sedimentary, and metamorphic) can be subjected to sufficient heat and pressure to alter their structures. As a consequence, all rocks have a metamorphic equivalent. The metamorphic rock type depends on the original rock characteristics and the nature, intensity, and duration of the metamorphic activity that it has undergone.

Metamorphic rocks are the least common of the three rock types found on the earth surface. They are more often found below the surface, deep within the crust. When they are exposed, it is usually due to tectonic activity that has resulted in uplift.

Examples of metamorphic rocks are gneiss, schist, slate, and marble. Gneiss and schist typically form from the metamorphism of quartz and feldspar rich parent rocks. Slate forms from parent rocks rich in clay minerals. Marble forms from limestone and dolomite parent rocks.

<u>Composition</u>

The composition of metamorphic rocks is dependent on the composition of the parent rock. The chemical composition is not changed from the parent rock because no net movement of material into or out of the rock mass usually occurs. However, the mineral composition is frequently changed with the formation of minerals that are stable at higher temperatures and pressures.

Identification

Metamorphic rocks show evidence of change resulting from the processes of heat and pressure. As a result, some metamorphic rocks may be identified by distortions in shape, through separation of minerals within the rock especially into bands or swirls often of different colors, and through bending of layers within the rock (not to be confused with folds of rocks layers that are discussed below).

Properties

Metamorphic rocks, because of the variety of parent rocks and the differences in time and intensity of metamorphic processes to which the parent rocks have been subjected, exhibit a variety of properties. Intense metamorphism results in high grade metamorphic rocks that are similar to some intrusive igneous rocks such as granite. Less intense metamorphism may not change the character of the parent rock very much at all. Harder, higher grade metamorphic rocks may be highly fractured and, therefore, may be good transmitters of groundwater. Lower grade metamorphic rocks are usually not highly fractured and because of their low permeability can be poor ground-water transmitters. Marble, the metamorphic equivalent to limestone, can be a good transmitter of groundwater when caverns or fractures are present.

b. Describe the elastic properties of rocks.

Rocks respond to stress by elastic deformation, plastic deformation, and rupture. Stress is the force placed on the rock mass. Strain is the deformation that is caused by the stress. The weight of the overlying body of rock places a downward force on the rocks that is balanced by an upward force from the incompressibility of the rocks below. These forces stress the rocks proportional to the depth of burial and the density of the overlying rocks.

If a rock body is subjected to directed forces, it usually passes through the three stages of deformation listed above. At first, the deformation is elastic; that is, if the stress is withdrawn, the body returns to its original shape and size if the stress does not exceed the elastic limit. If this limit is exceeded, the rock body does not return to its original shape. Below the elastic limit, for certain conditions in certain types of rock, engineers can simplify the deformation of the rocks to obey Hooke’s law, which states that strain is proportional to stress.

If the stress exceeds that elastic limit, the deformation is plastic; that is, the rock mass only partially returns to its original shape even if the stress is removed. When the stress increases, one or more fractures develop, and the rock mass eventually fails by rupture. Brittle rocks are those that rupture before any plastic deformation occurs. Ductile rocks are those that undergo a large interval of plastic deformation between the elastic limit and rupture.[2]

c. ***Describe the strength properties of rocks.***

Strength, sometimes referred to as rupture strength, may be defined as the force per unit area necessary to cause rupture at room temperature and atmospheric pressure in short-time experiments. Under these conditions most rocks are brittle and; consequently, little or no plastic deformation precedes rupture.[2]

However, rocks at depth are subjected to conditions that are not represented on the earth surface. Other important factors to rock deformation are confining pressure, temperature, time, and solutions. Experiments have shown that rocks can withstand greater compressive stress when they are under higher confining pressure, pressure associated with depth of burial. Consequently, rocks become more ductile with depth of burial and will deform plastically under the same compressive stress that would result in rupture at the surface.[2] Increasing temperature also increases the range of plastic deformation before rupture occurs.

Deformation of rocks has been shown to occur if even a small stress is placed on the rocks for a long time period. Creep refers to slow deformation under stress acting over long time periods. Ordinarily creep is restricted to deformation resulting from stresses below the elastic limit but the term is also applied to plastic deformation under any long-continued stress, even if the stress exceeds the elastic limit.[2]

It is prudent here to briefly discuss the difference between the strength of an intact rock sample and a rock mass.[3] An intact rock sample from a core in the field can be tested in the laboratory and dozens of coefficients, properties, responses, and graphs can be generated from the sample. For these tests, however, an intact rock sample is used. No discontinuities, faults or joints are present in this sample, although stratification is allowed and tested in an orientation similar to that found in the field. These properties and constants can lead to an under design of the project. This under design can occur because in the rock mass in the field, its strength properties are governed not by the elastic tests done on a core sample in the lab, but by the properties and constants of the joint sets, fractures and discontinuities found on the site. Unless the rock mass is unfractured and unjointed like the sample tested, more complex models must be created to adequately predict field responses. An analysis must be completed on the normal and shear forces encountered on the planes of fracture and jointing. Discontinuities must be handled on an individual basis. For water pressure, the roughness of the joint and the material filling a fracture may have more influence on the overall strength of a rock mass than the elastic properties of an intact rock sample.

d. ***Describe the geometry and properties of the following rock masses and effects on contaminant movement:***

- Folds;
- Faults;
- Structural discontinuities;

- Shear strength of discontinuities;
- Residual stress;
- Sheet joints; and
- Fractures.

Folds

Folds are undulations or waves in the rocks. Folds are best displayed in stratified rocks such as sedimentary and volcanic rocks, or their metamorphosed equivalents. However, any layered rock, such as banded gabbro or gneiss, may display folds. Folds may be developed over very small distances of less than an inch, be several feet or even miles across. Folds can even have continental proportions of several hundred miles.[2]

Anticlines are folds that are convex upward. Anticline, in Greek, means “opposite inclined”. It refers to the characteristic, in the simplest anticlines, of the two sides or limbs being inclined or dipping away from each other. In anticlines the oldest rocks are exposed at the center of the fold. Anticlines generally result from compressive forces that push the earth surface together.

Synclines are folds that are concave upward. Syncline, in Greek, means “together inclined”. It refers to the characteristic, in the simplest synclines, of the two limbs dipping toward each other. In synclines, as opposed to anticline, the youngest rocks are exposed at the center of the fold.

These simple folds can be greatly complicated by forces within the crust. Folds can be overturned such that the limbs actually dip in the same direction. They can be repeated forming a series of alternating anticlines and synclines.

In a plateau area, where strata is relatively flat, the strata may locally assume a steeper dip. Such a fold is a monocline. The beds of a monocline may dip a few degrees to 90 degrees, and the elevation of the same bed on opposite sides of the fold may differ by several hundred to thousands of feet.[2]

Groundwater tends to flow within permeable strata that act as aquifers and tends to be confined by less permeable strata that act as aquitards. Flow is, therefore, controlled by the permeable character of the various layers of the subsurface. The difference in elevation between the recharge area and the point of discharge is the force referred to as the head that causes groundwater to flow. Therefore, flow tends to follow the topographic surface with groundwater flowing from the highest point, the recharge area, to the lowest point, the discharge area. In unfolded rocks groundwater flows along permeable beds to a point of withdrawal such as a spring, water body, or pumping well. This flow is disrupted by strata that are dipping and flow may be channeled in some other direction than that which would be expected based on the topographic surface. Flow may be directed around an anticline if the oldest rocks (the rocks at the center of the fold) are less permeable than those in the limbs. Therefore, it is the permeability differences in the different strata and the relative positions of these strata that control ground-water flow around or through folds. Each case must be analyzed individually to determine how the fold geometry and the permeabilities of the rock strata direct ground-water flow.

From an engineering perspective, folds can also increase the vertical stresses in the rock layers surrounding the fold. It is possible for the vertical stress can go up by as much as 60%. With changes in the vertical stress, the horizontal stresses are increased by a factor of the vertical stress. Different portions of the fold can see drastically different stresses, and even if this material is homogenous, the varying horizontal and vertical stresses can induce strength, porosity and deformation anisotropy. The stress induced anisotropy can require design changes in an engineered structure if located near the fold.

Faults

Stress placed on rocks results in deformation. If the deformation caused by the stress proceeds far enough, the rocks eventually fail by rupture. Failure by rupture is expressed in the rocks of the outer shell of the earth's crust by joints, faults, and some kinds of cleavage.[2] Rocks are characteristically broken by smooth fractures known as joints. Joints may be defined as divisional planes or surfaces that divide rocks, and along which there has been no visible differential movement of the rocks parallel to the plane of the joint. A fault occurs when differential movement in a direction parallel to the plane of the joint has occurred. If movement at right angles to the joint surface takes place the resultant feature is called a fracture.[2]

The attitude of fault planes that result from horizontal tensional and compressional forces is usually not vertical. Therefore, the rock on one side of the fault is essentially beneath the fault plane. The rock beneath the fault plane is called the foot wall and the rock above the fault plane is the hanging wall. Faults result from either tensional or compressional forces. Tensional forces result in a lengthening of the rock mass. Lengthening the rock mass causes distinctive relative movement along a fault plane. If a fault occurs as a result of tensional forces, the relative movement of the hanging and foot walls is for the hanging wall to move downward relative to the foot wall. Such a fault is called a normal fault. Compressive forces tend to shorten the affected rock mass. Movement along a fault resulting from compressional forces is for the hanging wall to move upward relative to the foot wall. Such a fault is called a reverse fault. Thrust faults are a special case of normal faults in which the angle of the fault plane is particularly low. The relative movement along a thrust fault plane can be extensive resulting in considerable crustal shortening.

Shearing stress may be imposed on a rock mass. Shear stress results in lateral movement along the fault plane of the rock masses relative to each other. Such faults are called strike slip faults. Strike slip faults can have a vertical plane.

Faults, fractures, and joints can have considerable impact on ground-water movement. Open fractures obviously offer an easy route for water movement. Fractures are the principal method for movement of groundwater in igneous and most metamorphic rocks because these rocks are usually not porous. However, fractures usually do not have large volume and, consequently, do not hold large volumes of water. Therefore, water will move quickly through fractures but the volume of water involved will be small unless the fractures either have wide openings or the fractured rock is porous or in contact with porous and permeable rocks. Faults may have a variety of hydraulic properties. Faults that form from compressional forces may actually seal existing permeable rocks. The compressive force in these cases causes the minerals along the fault plane to recrystallize and fill the existing pore space. Faults and fractures may have been conduits for mineralized solutions. These solutions could have deposited sufficient minerals in the fault or fracture to completely fill the void and essentially seal it to further ground-water migration.

Structural Discontinuities

Discontinuities in rocks are characterized by an abrupt change in rock type. If strata suddenly end against different rock beds, a fault may be present. Discontinuity of rock structures is characteristic of faults, but is not proof of faulting unless other possible interpretations are eliminated[2]. Fault related discontinuities occur when movement along a fault results in dissimilar strata coming in contact with each other across the fault plane.

Structural discontinuities can impact ground-water movement. Abrupt permeability changes can occur at a structural discontinuity if the permeability of the rocks on either side of the fault plane are greatly different. An increase in ground-water mobility can occur if a saturated low permeability rock is in contact with a high permeability rock through such a discontinuity. This may result in unexpected movement of contamination.

Shear Strength of Discontinuities

Shear strength of a rock mass is the resistance of that mass to deform by slippage along an internal plane. Shear strength of a discontinuity is the mutual resistance of the two rock masses on either side of the discontinuity to slip along the plane of the discontinuity. Shear strength is a function of the discontinuity geometry and other characteristics related to its genesis. A highly undulating plane of discontinuity would have more resistance to movement than would a flat plane discontinuity. A discontinuity along a normal fault that resulted from tensional stress may be weaker than one along a reverse fault that resulted from compression stress because of the increased pressure from compression may have effectively welded the rocks across the discontinuity together.

In other types of discontinuities rock masses may have been invaded by dikes of rocks that are less resistant to weathering. In these cases the dikes, because of increased weathering, may be weaker than the invaded rocks and the shear strength of the discontinuity will be low.

The shear strength of the discontinuity will in itself not impact ground-water movement. However, if the discontinuity is characterized by hard impermeable rocks or rocks that have been highly recrystallized by the forces that resulted in the discontinuity, ground-water movement may be impeded. Also, if the discontinuity is highly weathered and the weathering results in conversion to clay minerals, the movement of groundwater may be impeded. On the other hand if the discontinuity is characterized by highly fractured rocks that have not been welded by recrystallization, ground-water movement may be enhanced.

Residual Stress

Residual stress is the stress that remains in the rock mass after some release in stress energy has occurred. Such a release may be associated with movement along a fault during an earthquake. An earthquake occurs when the stress within the rock mass exceed its elastic limit. Movement occurs and some part of the energy associated with the stress on the rock mass is released. In general, not all of the energy may be released and that which remains is the residual stress. In tectonically active areas stress continues to build until another earthquake occurs.

Another example of residual stress is stress in a rock mass that remains after a glacial mass has been removed by melting. The weight of a glacier pushes the underlying rock mass downward. The elevation of the rock mass is actually depressed under the weight of the glacier. After the glacier melts the depressed rock mass rebounds through a process of isostatic readjustment. Isostatic readjustment lags behind the unloading of the crust caused by the melting glacier. The lag is a result of the time necessary for material deep in the crust and the upper part of the mantle to move under the area of reduced load.[4] The rocks within the crust are under a residual stress after the glacier melts but before they return to isostatic equilibrium.

Sheet Joints

Sheet joints, or sheeting, are somewhat curved joints essentially parallel to the topographic surface. The joints are close together near the surface, in many places the interval between joints may be only inches. The intervals between the joints increases with depth and a few tens of feet below the surface sheeting disappears. Sheeting is best developed in granite-like rocks but can occur in sandstone.[2]

The effects of sheet joints on ground-water flow is similar to that of fractures. However, sheeting effects will only be noticed in groundwater within a few tens of feet of the surface where sheet joints exist.

Fractures

Fractures are defined as joints in which the movement of the rocks on either side of a joint is perpendicular to the plane of the joint. This movement results in opening of the joint to form a void space in the rock mass. Fractures are caused by stress that result in failure by rupture of the rock mass. Fractures can form during folding, faulting, intrusion, volcanism, erosion, and weathering of the rock mass. The geometry and patterns of fractures and their distribution is related to the rock type and stress characteristics.

Control of ground-water flow by fractures has been discussed above under faults.

e. ***Discuss the use of geological and geotechnical maps.***

Geologic and geotechnical maps illustrate stratigraphic and structural relationships between rock units exposed at the surface and are used for geological investigations (e.g., mineral and ground-water investigations) and geotechnical investigations (e.g., citing dams, power plants, buildings, slope stability studies, etc.). Geologic cross-sections drawn through select areas of the map allow the geologist to construct a three-dimensional view of the subsurface by extrapolating the rock units to show their structural and stratigraphic relationships at depth and, in some cases, in the air as they would appear if not eroded. Geologic maps and associated cross-sections can be used to show and interpret the structural and stratigraphic influences upon ground-water systems (confined and unconfined), slip surfaces of landslides, and detailed descriptions of the geotechnical properties of the rock units.

f. ***Describe a geomorphic system and cite an example.***

Geomorphic systems or geomorphic processes act to shape the land surface. Geomorphic systems include the action of wind, precipitation, movement of surface and groundwater, and waves as associated with climatic induced actions such as freezing on the geologic materials present to form a landscape. An example is the catastrophic floods from Lake Missoula, as recently as 15,000 years ago, that acted to reshape the land surface and created dramatic landforms known as the Channeled Scabland that includes lakes, giant flood bars and ripples, terraces, couless, and hanging valleys. Another example is the action of groundwater on limestone to form karst terrains common to many places in the United States.

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[1] Howell, J.V., *Glossary of Geology and Related Sciences*, 2nd ed., American Geological Institute, Washington, D.C., 1966.
[2] Billings, Marland P., *Structural Geology*, 2nd ed., Prentice Hall, Englewood Cliffs, NJ, 1965.
[3] Goodman, Richard E., "*Intoduction to Rock Mechanics*," 2nd ed., John Wiley and Son, Inc., N. Y., 1989.
[4] Zumberge, James K., *Elements of Geology*, John Wiley and Son, Inc., N. Y., 1965.

1.10 Civil/structural engineering personnel shall demonstrate a working level knowledge of the Department design and construction processes.

Supporting Knowledge and/or Skills

a. Discuss the accepted Department design process to include:

- **Congressional project approval process**

1. INTRODUCTION. Determining the appropriate funding source for an activity is an important and crucial decision that plays a major role in maintaining the financial integrity of a Department of Energy project. Once it has been determined that an activity is (or relates to) a construction project, there are additional considerations/actions that are required for the project. This section of the guide will discuss construction projects and describe the process involved in the Congressional project approval and review process.

2. DEFINITION OF CONSTRUCTION: Construction includes any combination of the following:

   a. Design, construction, installation, and acquisition of land, buildings, or utility connections
   b. Significant upgrade and betterment of existing facilities
   c. Initial complement of equipment necessary to make the building a useable, complete facility.

3. TYPES OF CONSTRUCTION PROJECTS: There are basically four types of construction projects:

   a. General Plant Projects
   b. Line Item Projects
   c. Major Projects
   d. Major System Acquisitions

Types of Construction Projects and Funding Limits for Eaeh:

Type of Project	General Description	Total Estimated Cost
General Plant Project	Miscellaneous minor new construction projects of a general nature. Provide flexibility to respond to changing facility conditions	< $2.0 million
Line Item Project	Specifically reviewed and approved by Congress and DOE Headquarters. Generally provide land and/or facilities for long-term programmatic	> $2.0 million

	support and administrative needs of DOE sites.	
Major Projects	Projects directed at and critical to fulfilling a DOE Mission, entailing the allocation of relatively large resources or warranting special management.	> $50 million < $100 million
Major System Acquisitions	Same as Major Project.	> $100 million

Note: Major projects and Major System Acquisitions are considered to be and are budgeted as line items (LIs) since they exceed the $2M threshold of the Total Estimated Cost.

4. TOTAL ESTIMATED COST (TEC): The Total Estimated Cost (TEC) of a construction project is the gross cost of the project including the cost of land and land rights; engineering, design, and inspection costs; direct and indirect construction costs; and the cost of initial equipment necessary to place the plant or installation in operation, whether funded out of operations or Plant and Capital Equipment funds. For projects that are capital funds, the TEC includes those project activities that are to be capital funded.

5. TOTAL PROJECT COST (TPC): TPC consists of all the costs included in the TEC of a construction project plus the preconstruction costs, such as conceptual design and research and development (R&D), plus the costs associated with the preoperational phase, such as training and startup costs. These project costs that are excluded from the TEC but are part of the Total Project Costs (TPC) are generally referred to as Other Project Costs (OPC).

6. KEY DECISIONS: Key decisions are approved byhte Acquisition Executive on all MSAs and selected MPs.

   The Secretary has delegated the principal responsibility for project management activities to the Acquisition Executive. This includes establishing Departmental project management policies, approving the Project Management System, serving as the chairman of the Energy System Acquisition Advisory Board (ESAAB) and Level Baseline Change Control Board (BCCP) for the Department MSAs and selected MPs, and approving the establishment of project offices.

   Key Decisions on MSAs and certain decisions on MPs are normally reserved for the Acquisition Executive. In some cases the Secretary may elect to act as the Acquisition Executive on critical projects. These include decisions to enter the acquisition phase or to make transitions between phases (Key Decisions) and any decisions that will directly result in commitment of major portions (that is, procurement of large, long-lead items) of the project funds. Additionally, the Acquisition Executive may reserve other decisions on a case-by-case basis. Assistant Secretaries make the Key Decisions on Major MPs not reserved for the Acquisition Executive.

OMB Circular A-109 specifies certain Key Decisions and outlines the logical sequence of activities for the MSA or MP process. Key Decisions may be expanded to include additional milestones or decision points. The following table outlines the Key Decisions.

Major Systems Acquisition and Major Project Key Decisions

Key Decision 0 - Approval of Mission Need	• Prerequisite for requesting conceptual design funding in the internal review budget cycle. • Approval must occur prior to the planning stages of the annual internal review budget cycle and submission of initial funding requests to the Office of Management and Budget and Congress. • Documentation requirement: Approving Mission Need. • Prerequisite for release of appropriated funding by the CFO.
Key Decision 1 - Approval of New Start	• Prerequisite for requesting project line item funding in the internal review budget cycle. • Approve Project Plan including initial project baselines. Initial technical, cost and schedule baselines for the project will be based on the Conceptual Design Report (CDR) and its support documentation. • Implement a change control system delineating specific responsibilities, authority and accountability at the appropriate management levels for changes affecting the project baselines. • Other input to the decision process includes completion of the budget validation, and independent cost estimate, and the project data sheet. • Prerequisite for release of appropriate funding by the CFO.
Key Decision 2 - Approval to Commence Title II or Final/Detailed Design	• Scheduled prior to start of Title II, or Final/Detailed Design. • Input to decision process includes update to the project baselines reflecting completion of preliminary design (Title I), and an independent cost estimate. • Current project plan reflecting approved baseline changes, as appropriate. • Approval to begin long-lead procurement, if applicable. • Prerequisite for release of appropriate funding by the CFO.
Key Decision 3 - Approval to Commence Construction or Enter full-scale Development	• Scheduled prior to start of construction or full-scale or full-scale development. • Input to the decision process includes update of project baselines reflecting completion of final/detailed design (Title II) and an independent cost estimate. • Current project plan reflecting approved baseline changes, as appropriate. • Other input to the decision process includes evidence of readiness to process, appropriateness of timing and a firm baseline. • Prerequisite for release of appropriate funding by CFO.
Key Decision 4 - Approval to Commence Operation/Production	• Scheduled prior to the transition from acquisition to operation/production; transition is not formally made until demonstrated capability to meet technical performance goals specified in the baseline. • Prerequisite for release of appropriate funding by the CFO.

5. SUMMARY: Construction projects are categorized based predominantly on the total cost or appropriateness for the project. General Plant Projects are those that

have a TEC of no more than $2M. Line Item Projects have a TEC of more than $2M. Major Projects have a TEC of more than $50M, but less than $100M. Those projects that have a TEC of greater than $100M are categorized as Major System Acquisitions.

- **Construction Project Activities**

  A construction project is comprised of many activities spread over a number of years. The following table summarizes the activities and identifies the appropriate funding source for each activity.

Funding Sources for Construction Project Activities

Construction Project Activity	Description	Funding Source
Pre-Title I	Activities that take place prior to the start of preliminary design	Operating
Title I	Preliminary stage of project design	P&CE
Title II	Definitive stage of project design.	P&CE
Title III	Inspection portion of project engineering, design, and inspection	P&CE
Construction	Activities involved in creating a new operational facility or significantly updating or adding to an existing facility. The initial complement of equipment required to make the facility operational is also included as part of construction.	P&CE
Startup Activities	Activities that take place during the transition from construction completion to operation of the facility.	Operating
Construction Management	Review and approval of construction packages, review and acceptance of construction test procedures, and control of field design change requests	P&CE
Project Management	Management services beginning with Title I and continuing through the completion of construction.	P&CE
Project Support	Technical support of the project manager by nondedicated personnel.	Operating

Budget Process

1. INTRODUCTION: This section of the guide describes the DOE budget process and outlines those areas appropriate to Congressional involvement for either review or approval status.

2. THE DOE BUDGET PROCESS: The DOE budget process is generally accomplished on a 20 month cycle. The process will be described after this portion of the guide which will be dedicated to the presentation of key Budget Terms and Concepts.

3. KEY BUDGET TERMS AND CONCEPTS: The following key budget terms and concepts will be used throughout the remainder of this portion of the guide.

A **fiscal year (FY)** is a defined 12-month period designated for business purposes. In DOE and other federal government organizations, a fiscal year starts on October 1 of a given year and ends on September 30 of the following year.

Budget Year (BY)- usually the next fiscal year for which a budget will be submitted to Congress. For budget validation purposes, the BY is the FY for which budget estimates are being developed and is two fiscal years from the current execution year (the execution year is the fiscal year in which the budget is being executed). The budget year can also be determined from the name of the submission or review. Because budget cycles overlap, there may be more than one active budget year at any given time.

The following terms have two meanings: a budget formulation meaning, which is relative and changes from one budget cycle to the next, and a budget execution meaning, which is absolute and does not change.

Current Year (CY) - Budget Formulation : Meaning: The fiscal year before the budget year. It is also the year that will be in execution when the next budget is sent to Congress.

Budget Execution: Meaning: The current fiscal year.

Prior Year (PY) - Budget Formulation: Meaning: Year before the current year. It is also the fiscal year that will be the most recent actual year when the next budget is submitted to Congress.

Budget Execution: Meaning: Year before the current year.

Outyear (s) (OYs) (BY=1, BY=2, etc.) Year (s) beyond the budget year.

4. BUDGET PROCESS

   a. Issuance of Budget Guidance:

Although operations offices initiate the budget process as early as November, the official DOE budget process begins with DOE Headquarters (HQ) issuing guidance for preparation for the budget.. The annual field budget call (also referred to as the Unified Budget Call, or Unicall) provides program and budget guidance and sets forth specific requirements, schedules, and due dates for the budget-year request. It is meant to supplement the requirements defined in the DOE Orders and the *DOE Field Budget Formulation Handbook.*

Normally the Chief Financial Officer issues the Unicall in December or January, (that is, in January 1997, the Chief Financial Officer will issue the budget call for BY 1999.)

b. Field Budget Review

Using the Unicall and other DOE guidance, most DOE contractors submit their budgets to DOE-HQ through the operations offices, (previously Field Offices). The operations offices are to review the budgets and submit their comments to the appropriate Assistant Secretary (AS). A few contractors may submit their budgets directly to DOE-HQ with copies being concurrently sent to the operations offices. Budgets are organized along DOE AS program instructions.

The budget package normally includes the following:

(1) Summary of estimates tables.

(2) Narrative justification of the estimates.

(3) Backup documents that support the estimates including:

- Work Package Documents;
- Impact Summary Of Activities Funded In Prior Years; and
- Crosscut Schedules.

The operations offices review and approve budget requests and submit them to the Assistant Secretary (AS).

c. Assistant Secretary Budget Review

The respective AS, or equivalent, reviews the field budgets, makes any necessary revisions, and then sends the product of their review (their Internal Review Board (IRB) submission) to the DOE Chief Financial Officer (CFO).

d. IRB Review

The CFO reviews the AS representatives' budget requests for logic, justification, and consistency with Departmental policy/mission and OMB targets/requirements. The CFO, in consultation with an AS representative, develops policy and funding recommendations that, historically, have been sent to the Secretary for review and approval. After the Secretary has approved the budget, the CFO oversees the preparation and submission of the total DOE budget to OMB.

During the FY 1995 budget process, the Secretary established a critical support team made up of the principal AS representatives. The purpose of this team was to review the budget and, through consensus, develop Department-wide funding levels within preestablished parameters. This team may have continuing responsibilities in future budget processes.

e. OMB Review

OMB reviews the budget for logic, justification, and consistency with Administration policy/mission and target/requirements. Total federal budgets, as well as recommended adjustments, are sent by OMB to the President for review and approval. After the President has approved the budget, OMB oversees the preparation and submission of the budget to Congress. Government-wide, this budget is known as the President's Budget. It is also known as the Congressional Budget Submission.

f. Congressional Budget Review

Congress conducts hearings on the budget and appropriates funding. An Appropriations Act provides federal agencies the authority to incur obligations and to make payments out of the Treasury for specified purposes. This authorization is normally expressed as Budget Authority. Budget Authority is the value of legal authority to incur obligations.

Funds appropriated in an Appropriations Act are categorized into many appropriations. An appropriation account is established by the Department of Treasury for each appropriation. DOE receives an appropriation that has historically been divided among operating, capital equipment, and construction funds.

Summary of DOE Budget Formulation/Justification Process

November	Field begins budget preparation.
January	Unicall issued to field. Operations Offices issue field b budget guidance to their reporting entities.

March/April	Field reporting entities submit budgets to Operations Offices. Operations Offices review budget submissions. Field Budget Submissions prepared by all offices that submit this budget to HQ.
April/May	Field Budget Submission due to HQ (AS/CFO). AS review Field Budget Submissions, prepare Internal Review Budget (IRB) Submission.
Mid June Through August	Internal Review Budget Submission due to DOE CFO. DOE CFO works with AS to refine and balance the budget within OMB targets. DOE Secretary or designee make final decisions on budget. OMB Budget Submission prepared by CFO/AS.
September 1	OMB Budget Submission due to OMB. OMB works with DOE to refine DOE budget, and balance federal budget within overall targets. President makes final decision on budget. Congressional (a.k.a. President's) budget prepared by DOE/OMB.
Early February	Congressional budget due to Congress.
February-June	Congress holds hearings on the budget.
September 30	Congress appropriates funding or passes continuing resolution.

Criteria to prepare a conceptual design report (CDR)

- **Conceptual Design Reports**

  1. GENERAL. The conceptual design report is a summary of the conceptual design results. The report contains the conclusions and recommendations reached as a result of the conceptual design. Heads of Field Elements shall determine the organization responsible for the preparation of the report. Normally, it will be the organization performing the conceptual design. Reports shall be approved and signed by the Head of the Field Element or his designee.

  2. COVERAGE. A conceptual design report shall be prepared for all construction projects for which conceptual designs are performed prior to inclusion of the project in the DOE budget reports. Reports shall be submitted to Headquarters.

3. CONTENTS. Arrangements, format, and content of the conceptual design report shall be determined by Heads of Field Elements. The following items shall be included as applicable:

   a. Official project number and title.

   b. Project justification.

   c. Detailed description of the project scope.

   d. Performance requirements for the project system or process.

   e. Total estimated cost including individual estimates for each title of design (I, II, and III), construction, standard equipment, uncertainties, and contingencies. Cost estimate methodology and backup details shall be included.

   f. Project design, procurement, construction, and environmental compliance schedules (critical path method schedule is recommended).

   g. Methods of performance for design, procurement, and construction with backup details.

   h. Work breakdown structure.

   i. Requirements and assessments for:

      (1) Safeguards and security;

      (2) Energy conservation;

      (3) Health and safety;

      (4) Environmental protection (detailed schedule for compliance with National Environmental Protection Act and other environmental review requirements as appropriate);

      (5) Decontamination and decommissioning;

      (6) Quality assurance;

      (7) Maintenance and operation;

      (8) Telecommunications;

      (9) Computer equipment; and

(10) Provision for handicapped and fallout shelters.

j. Analysis of uncertainties, contingencies, and effort required to resolve uncertainties.

k. Conceptual drawings and outline specifications.

l. Applicable codes, standards, and quality levels.

4. PROTECTION OF INFORMATION. Significant portions of conceptual design reports have been held by the courts to be exempt from mandatory disclosure under the Freedom of Information Act (FOIA) (5 U.S.C. 552), because the information is recommendatory in nature and includes information which will be instrumental in Government negotiations and which, if disclosed, would expose and jeopardize the selection process for A-E contractors.

   a. The Head of the Field Element responsible for a conceptual design shall assure protection of the conceptual design information. Only sufficient copies of the conceptual design reports as are necessary to meet its official purpose shall be generated. Distribution shall be limited to those individuals or organizations which are necessary to fulfill Department requirements.

   b. The following legend shall be included in each conceptual design report:

      "This Conceptual Design Report contains confidential commercial information that shall be used or duplicated only for official Governmental purposes, and this notice shall be affixed to any reproduction or abstract thereof. Disclosure of the confidential commercial information contained in this report outside the Government shall not be made without the advice of counsel. The restrictions contained in this notice do not apply to any data or information in this report which is not commercial information or to information generally available to the public on an unrestricted basis."

      - Actual preparation of a CDR
      - Justification and validation report

Guidance for Preparing a Justification of Mission Need

1. The Justification of Mission Need is the document required to obtain Department approval for expenditure of Department funds for projects anticipated for designation as major system acquisitions or major projects, which reflect the determination and identification of DOE mission need(s), based on the reconciliation of continuing analyses of current and forecasted capabilities, technological opportunities, overall priorities, and initial resource expenditure involved with achieving DOE's mission.

The Program Manager is responsible for Preparation of the Justification of Mission Need. The Justification of Mission Need should be a brief (three to six page) document expressing the project need in terms of the following elements:

a. Program mission/goal;

b. Project objectives;

c. Organization; and

d. Approvals.

2. Since the mission need is independent of any particular system or technological solution, the Justification of Mission Need shall not express the need in terms of equipment or specifications, although feasibility at this time via availability is relevant.

3. The Justification of Mission Need shall emphasize the reasons why project conceptual design funding should be approved by addressing the mission needs, the purpose and priority of the project in supporting the needs, the significant of meeting the needs, and shall include the following information:

a. Program Mission/Goal.

(1) Provide the mission of the program, a description of program goals to be accomplished and relationship to the Secretary's mission area assignments.

(2) State how the project will support the program goals and explicitly state why it is needed.

(3) How is the project related to program strategy; how does it relate to other program elements and projects?

(4) Why is it the appropriate next step and what would be the programmatic impact of not doing it at all?

(5) What are the most appropriate alternatives, if any?

(6) Why are these options being considered?

(7) Why is this the best option?

(8) Describe the appropriateness of the project at this time in view of the state of current technology.

b. Project Objectives.

(1) Technical Objectives:

(a) As specifically as possible, describe the technical objectives.

(b) Cite the basis for the feasibility of achieving the technical objectives (e.g., studies, research and development, state of related technologies).

(c) Discuss technical objectives in relation to similar ongoing or planned activities, both international and domestic.

(d) Describe the impact on the program of not meeting the technical objectives.

(2) Cost Objectives:

(a) Provide estimates of cost related to developing the Conceptual Design Report (CDR) and related documentation required for Key Decision 1.

(b) Provide discussion and justification of how the conceptual design funds will be distributed (profile) along with the major cost items.

(c) State when cost estimates resulting from conceptual design will be available.

(3) Schedule Objectives:

(a) Provide a statement of preliminary project schedule to include at least: (1) start conceptual design; (2) complete CDR; and (3) Key Decision 1, Approval of New Start.

(b) Describe the impact, if any, on the program of not meeting the schedule dates.

c. Organization. Provide a preliminary plan for organizational involvement and relationships, including, as appropriate, field organizations, laboratories, universities, industrial concerns, DOE Headquarters, or other agencies, foreign or domestic for the period between Key Decision 0 to Key Decision 1.

d. Risk Assessment.

(1) What is the probability of success?

(2) Describe the basis for risk assessment.

e. Approvals. The Justification of Mission Need shall be approved by the Acquisition Executive for MSAs and the cognizant Program Secretarial Officer for major projects. Concurrence of other program and staff officials, as appropriate, are required prior to these signatures. Include a specific statement of what the Acquisition Executive or the Program Secretarial Officers are supposed to approve (e.g., "This project as described in this Justification of Mission Need is recommended for inclusion in the FY '94 budget submission to OMB").

4. As mentioned, the Justification of Mission Need is required only for major system acquisitions and major projects. For projects other than MSAs and major projects, the project data sheet should be sufficient to serve as a justification if it contains the basic information required above, tailored by project size and complexity. There may be instances, particularly for projects approaching $50 million, when the Assistant Secretary may require a justification as part of the project documentation.

5. APPROVAL. The signature page for a Justification of Mission Need shall include only the following:

   a. SUBMITTED BY: Program Manager

   b. A paragraph that approves initiation of the major system acquisition project and directs development of a project plan for signature approval of the Program Secretarial Officer and the Acquisition Executive (Deputy or Under Secretary); and

   c. For major projects, the Program Secretarial Officer shall be the final approving official, except in cases where the Deputy or Under Secretary reserves approval authority.

6. REVIEW AND CONCURRENCE OF JUSTIFICATION OF MISSION NEED.

   a. Major System Acquisition. The Justification of Mission Need as approved by the acquisition proponent shall be transmitted to the Acquisition Executive via Action Memorandum. The concurrence chain on the Action Memorandum shall include concurrence of:

      (1) Assistant Secretary for Domestic and International Energy Policy;

      (2) Director of Program/Project Management and Control; and

      (3) Director of Procurement, Assistance and Program Management.

   b. Major Projects. DOE major project Justification of Mission Need are to be approved by the Program Secretarial Officer and transmitted to the Deputy or Under Secretary, as appropriate via Information Memorandum, with a copy to the

Director of Program/Project Management and Control. The acquisition proponent shall assure that the Assistant Secretary for Environment, Safety, and Health and the Associate Director of Program/Project Management and Control and Director of Procurement, Assistance and Program Management have concurred.

c. Full Implementation. After the contractor demonstrates compliance with the contractual requirements, a formal review report shall be prepared to document in detail how the contractor's management control systems comply. Based on this report, DOE issues a certificate of validation and the cognizant contracting officer officially notifies the contractor of the validation. The contractor shall then be required to update systems documentation, as necessary, to maintain an accurate description of the systems. Any changes are forwarded for review and approval by the DOE project manager prior to incorporation. Upon contractor request, a Memorandum of Understanding, referencing the validated systems, may be issued relative to application of the systems to other DOE contracts. The contractor may then respond to solicitations for potential contracts with similar requirements by citing the Memorandum of Understanding in his proposal.

Review and Approval of Design Criteria

1. Design Criteria. Development of design criteria for a facility begins at the time the need for a project is identified. The base of the criteria is the statement of the functional parameters that the facility must meet. These functional criteria are further developed, validated, and expanded during the conceptual design phase. The development of criteria which are complete and specifically related to the facility requirements allows for orderly development of the design. Completeness of the design criteria is emphasized. However, care shall be taken to avoid citing superfluous codes and standards; the primary purpose of design criteria is to narrow the criteria to only those applicable to a specific design effort. Prior to the selection of an A-E, the design criteria should be consolidated into a document that will provide guidance to the A-E. The design criteria document should:

   a. Briefly define the purpose of the project.

   b. Provide a general description of the project.

   c. Give the designer room to exercise expertise in the engineering design disciplines and to use up-to-date design and construction applications. The A-E shall use his or her knowledge and expertise to assure that maximum efficiency and cost effective concepts are included in the design, in accordance with Departmental guidelines.

   d. Provide all design requirements to be applied by the designer to meet the needs of a specific facility. Usually a narrative format is used (limits, capacities, quantities, and space allocations).

e. Incorporate or reference specific Departmental requirements, such as DOE 6430.1 and other applicable Orders.

f. Include plans developed to mitigate environmental impacts in accordance with the National Environmental Policy Act documentation and environmental permit and license requirements.

g. Refer to specific operating contractor requirements such as design standards, plant operating policies, and quality assurance manuals.

h. Identify applicable national and area codes, standards, and guides not specifically identified in DOE 6430.1. If certain sections or parts of a specific code or standard are not applicable or are exceeded by a more stringent code or standard, this fact should be stated in the criteria document.

2. Design Criteria Package. The availability and use of a well-prepared design criteria package allows the designer to proceed with the design with a minimum of delays, allows for better management of the design, and prevents problems from arising during design work due to lack of project definition at the beginning. This package shall be provided to the designer prior to start of design and should contain as a minimum:

   a. The following information related to performance of engineering design:

      (1) The design criteria document(s).

      (2) Studies, reports, and conceptual designs related to the project.

      (3) Copies of DOE 6430.1, applicable documents referenced therein, and any additional energy conservation, environmental, safety, and health standards, including National Environmental Policy Act documentation.

      (4) Copies of applicable operating contractor standards, guides, and manuals such as design standards, plant policy and operating standards, quality assurance program manual, and cost estimating guides.

      (5) Sketches or drawings developed during conceptual design which contain necessary information related to the specific facility, such as:

         (a) Site and location plan;

         (b) Typical floor plan;

         (c) Typical elevations;

(d) Existing utilities plan and information;

(e) Equipment layout plan and listing (operations or production);

(f) Special systems layout plan and listing;

(g) One-line piping and instrumentation diagrams (process or production flows); and

(h) Other pertinent information.

(6) Information available on standard and special equipment items (this does not include building systems) such as:

(1) Government furnished and operating contractor installed equipment (only if pertinent to design needs);
(2) Government furnished and construction contractor installed equipment; and

(3) Construction contractor procured and installed equipment.

b. Other information related to criteria and performance of design (usually separate attachments to the criteria package):

(1) Listing of Departmental and contractor computer programs available for use by the designer and how they can be obtained.

(2) Listing of related submittals such as reports, calculations, conceptual design, and costs.

(3) Required drawing size and list of suggested drawings and titles (separate attachments with the criteria package).

(4) Estimated cost of construction breakdown thereof.

(5) Copies of information pertaining to the management of the project (project management plane.

(6) Information pertaining to procurement of construction, such as bid package structure, required contract clauses, and types of specifications.

c. A checklist which may be used as a guide in preparing or reviewing criteria packages is provided in Attachment V-3.

Design Criteria Package Checklist

This checklist is intended as a guide to ensure the development of a complete criteria package. Field Elements may add to this checklist as necessary to meet their particular requirements. The checklist items are considered necessary to be included within the criteria package to ensure that adequate information is provided for the designer of the facility. The criteria package should:

1. Describe the functions or operations to be performed in the facility or project.

2. Provide a general description of the planned or proposed facility as conceived in the conceptual design, including:

   a. Proposed occupancy, type of buildings, parameters, work spaces, and special needs;

   b. Site location;

   c. Site preparations, conditions, removals, temporary roads, fencing, work areas, disposal areas, borrow area, grading, drainage, and excavations;

   d. Site improvements, parking, roads, walks, fencing, and lighting;

   e. Utilities, existing and proposed; and

   f. Special security, environmental, safety, and health needs.

3. Refer to and include copies of applicable publications or information, such as:

   a. Departmental directives, studies, and references; and

   b. Operating contractor manuals, standards, and references.

4. Refer to applicable codes, standards, or guides.

5. Provide a general description of building requirements, including:

   a. General proposed layout and configuration;

   b. General operational or functional needs and special functional or system needs;

   c. Building fenestration and orientation;

   d. Dead and live loads, special loads, and wind loads;

   e. General building structure or frame;

f. Foundation and soil conditions;

g. Walls, exterior and interior, and finishes, including insulation, moisture protection, doors, windows, and vestibules;

h. Roofing, moisture proofing, insulation, walkways, hatches, ceilings, and finishes;

I. Floors and finishes;

j. Energy usage targets and/or limits; and

k. Fixed fire protection features such as fire rated walls, doors, windows, and interior flame spread ratings.

6. Provide general description of the building mechanical systems requirements, including:

a. General heating, ventilation and air conditioning needs and requirements, heat recycling and/or recovery, monitoring, and control.

b. General heating, ventilation and air conditioning parameters, including:

(1) Occupancy loads and operations uses;

(2) U values for the building envelope;

(3) Design temperatures and humidity control;

(4) Controls systems; and

(5) Instrumentation.

c. Codes, standards, and guides.

d. Energy conservation parameters.

e. Special conditions or parameters, including:

(1) Special systems or equipment loads; and

(2) Special ventilating and filtering information.

f. Piping and plumbing needs, including:

(1) Codes and standards;

(2) Process water or cooling water needs; and

(3) Cooling water chemistry control needs.

g. Fire protection.

h. Systems performance and operating tests.

7. Provide general description of building electrical systems requirements, including:

a. Lighting needs.

b. Power needs.

c. Electrical systems parameters including:

(1) Occupancy and operations use;

(2) Illumination guides and proposed methods; and

(3) Control measures.

d. Codes, standards, and guides.

e. Energy conservation measures.

f. Special conditions or parameters, including:

(1) Equipment loads and information; and

(2) Special system information.

g. Emergency or backup power, including:

(1) On site power from diesel generators; and

(2) Backup power from independent power transmission lines.

h. Lightning protection and grounding.

I. Controls and Instrumentation.

j. Fire detection and alarm systems.

8. Provide general description of alarm, detection monitoring, and control systems, including:

   a. General definition of systems:

      (1) Safety;

      (2) Security;

      (3) Controls; and

      (4) Fire Protection.

   b. One-line diagrams and information.

   c. Codes, standards, and guides.

   d. Systems checkout and test requirements.

9. Provide general description of special facilities, equipment, or systems, including:

   a. General definition of facilities, equipment, or systems;

   b. Participants and roles for design, procurement, and installations;

   c. Layout configuration and identification;

   d. Piping and instrumentation diagrams; and

   e. Equipment service needs, loads and information, including:

      (1) Electrical and mechanical; and

      (2) Ventilation and filtration.

10. Provide general description of standard equipment, including:

    a. Definition of standard equipment;

    b. Participants and roles for procurement and installation;

    c. Layout and identification; and

    d. Service needs and loads.

11. Provide general description of quality assurance measures, including:

    a. General quality assurance levels, including:

        (1) Project;

        (2) Architectural and civil;

        (3) Mechanical;

        (4) Electrical; and

        (5) Special facilities and standard equipment.

    b. Quality assurance manual and/or guides (examples or copies).

12. Provide general information relating to:

    a. Required procurement clauses;

    b. Type of specifications;

    c. Contents of bid packages;

    d. Available computer programs; and

    e. Available reports and calculations related to the project.

13. Provide a listing of suggested drawings and titles

14. Provide required drawings size, type, and number of copies.

15. Provide estimated cost of construction and breakdown by cost elements.

Architect/Engineer (AE) Selection Process

1. Architect-Engineer Selection. Selection procedures for architect-engineers (A-Es) shall be in accordance with subpart 936.6, "Architect-Engineer Services," of the Department of Energy Acquisition Regulations. It is emphasized that, prior to the selection procedures, the professional experience and qualifications required for each project are accurately identified, and the evaluation criteria and prerequisites that are developed for each A-E services procurement adequately reflect these requirements. Prior to A-E selection, field office managers must ensure that the project design criteria package is complete and complies with DOE 6430.1.

2. Traditional Engineering Services. These services which encompass Titles I and II as defined above, are normally performed by architect-engineer firms under DOE prime or subcontract arrangements. To obtain the highest qualified professional services available, Departmental Elements shall comply with the policy and procedure set forth by the Brooks Bill, (40 U.S.C. 471, et seq.); DOE implementing regulations; and OMB Circular A-76. Operating contractors may perform Titles I and II work when it is determined by the field office manager to be in the best interest of the Government and is not a violation of the policy and procedures set forth by the references cited above.

   Projects for which the operating contractor might perform design services include those for which the design involves a high degree of interfacing with existing equipment, operations and/or facilities; work is closely tied to ongoing research and development; and/or special expertise and knowledge is required which is generally only available to the operating contractor.

Design Approval Process

1. Design Approval Process.

   a. The scheduling of definitive design shall be based upon a detailed analysis of a project and its component parts. Engineering work involved in defining equipment and materials having long-lead procurement time shall be scheduled for early completion, in order that procurement can be initiated prior to the construction contracting when timing would make inclusion of the procurement as part of the contract infeasible. When construction is to be performed under a number of fixed-price contracts or under a cost-plus-fixed-fee contract, construction drawings and related documents should be scheduled in the sequence required for construction operations.

   b. Of major assistance in scheduling the performance of definitive design is the early establishment of detailed schedules of the need for drawings and specifications to support construction and procurement. Such detailed schedules assist in determining engineering manpower requirements and assure that completion of individual documents meet procurement and construction schedules.

2. Periodic and Final Design Reviews. As a vital part of the overall management of the project, periodic design reviews need to be performed during the preliminary (Title I) and definitive (Title II) design to assure that project development and design are proceeding in an orderly manner; assure that the project will satisfy program and operating objectives; review performance, schedules, and costs; identify potential and real problem areas; and initiate action for timely solutions and corrective measures. Procedures for conducting, monitoring, and controlling these necessary design reviews must be developed by the Heads of the Field Elements. In addition to procedures for design

review, Heads of the Field Element shall develop procedures for the distribution and approval of design documents.

3. Design and Construction Scheduling and Methods of Performance.

   a. Scheduling.

      (1) Considerations Pertaining to Performance Time of Contractors and Effects on Cost. To the extent possible, schedules for engineering, procurement, and construction services shall be established concurrently to assure assignment of adequate time for performance and to properly coordinate the accomplishment of the services. Construction completion of project elements shall satisfy operating requirements, including time for tests and adjustments prior to operation. If required completion dates do not permit normal performance periods, the available time must be allocated to achieve maximum overall economy, based on a careful determination of the feasibility and cost of performance of each service in less than normal time (i.e., with premium time). Sometimes the total time available may not, by any reasonable allocation, allow completion of all design prior to starting construction. Under such conditions, the design shall be scheduled so that logically separable portions of the work, such as site work, foundations, superstructure, mechanical, and equipment installation can be awarded as separate contracts, bearing in mind that for maximum effectiveness a contractor should have, subject to security limitations, full control of the area in which he is working. However, it may be necessary to perform both engineering and construction on a cost-plus-fixed-fee basis so that both can proceed concurrently. Where plans involve use of more than one fixed-price contract for construction, special care should be taken to assure that the plans and specifications clearly and completely define the scope of work to be accomplished under each contract. Sequential fixed-price contracts should be scheduled to permit orderly progress and timely completion.

      (2) Considerations Pertaining to Performance Times Required to Accomplish Administrative Actions. Past experience indicates that schedule delays have occurred on many projects due to the insufficient allowance for the time required to accomplish the administrative functions on the project. In scheduling the work, proper consideration shall be given to the time required for such activities as the selection of the architect-engineer selection of a cost-plus-fixed-fee construction contractor, administrative approval requirements, and bidding and award of fixed-price construction or procurement contract(s). The field office manager shall determine the type and number of architect-engineer contracts to be used and the most appropriate type of contractual arrangements required. During the course of preliminary and definitive design, the field office manager reviews and firms up the preliminary determination as to the type and number of construction-contracts to be used. Field office

managers should ensure that realistic times are scheduled for selection of architect-engineer and construction managers, appropriate administrative approvals, and award of procurement and construction contracts. Appropriate procedures and controls shall be established and utilized for the accomplishment of these administrative functions that will ensure on-time completion of these actions.

(3) Use of Logic Diagrams. During the entire process of scheduling, the use of logic diagrams can be extremely helpful to the planner or scheduler to recognize the relationships between the various actions required on a particular project. It must be recognized that perhaps the largest benefit from the use of the performance evaluation review technique (PERT) or critical path method (CPM) can be gained during the early phases of project design. Design decisions and regulatory requirements during the design phase may create considerable changes to the project logic. In some cases, a design or other decisions may have such an effect on the project cost and schedule to require a modification or reversal of the decision. For this reason, the project manager must continually revise and utilize the logic diagram.

b. Methods of Performance.

(1) General. In determining the manner and method of performance, consideration should be given to constantly evolving innovations which may result in improvements in the traditional methods of design and construction of buildings and facilities required for accomplishment of programs. New techniques and new ways of doing things may provide solutions to new challenges and problems which may arise. New practices should be adopted which will reduce design and construction time; use of other cost saving techniques should be maximized; and new methods of contracting should be considered which will produce economies in construction costs. Use of performance-type specifications may permit the application of new technology and produce improved designs to meet requirements. In adopting any new techniques or methods, care should be exercised to assure that the design criteria are satisfied, and that the results will be achieved without any decrease in desired quality and without any sacrifice in essential requirements. Methods of performance and scheduling must be considered together, comparing the advantages of a method with the effect it has on the schedule and cost. During the design phase of a project, this interaction between these two important actions must be continually considered. Construction contracting and erection methods can greatly affect the design method and sequence and should be determined early in the design phase. Field office managers must ensure that provisions for the above considerations are included in the project management plan.

(2) Cost Estimates. The importance of continual development of the project cost cannot be overemphasized particularly under the current market conditions of rapidly rising costs. Inclusion of "nice to have" features in the design, and failure to consider improved construction methods will contribute to excessive project cost growth. Consideration of cost during design evaluations can limit this growth, as well as facilitate the preparation of the formal cost estimates required during the life of a project. Further information and guidance on cost estimates is contained in Chapter II of this Order and DOE 5700.2C.

b. Discuss the Department construction process following a project's certification for construction.

- Differentiatebetween direct-hire and indirect-hire construction contracts.

  Direct hire construction contract is a contract directly with DOE for construction. Indirect hire construction contract is one which the construction contract is made with a subcontractor to DOE.

  Note: The terms direct hire and indirect hire construction contracts are not defined in any DOE documentation. The terms may not be used at all DOE facilities.

- Discuss the role of Department civil/structural engineering personnel in the construction process.

  1. Project Manager. The project manager has direct primary responsibility and accountability for the management of the construction effort. He or she normally will be designated as the contract administrator or contracting officer's technical representative for the construction effort by the contracting office. Among the usual functions of the project manager are the following:

     a. Assures that cost, schedule, and scope requirements are met;

     b. Acts as the principal contact and serves asthe liaison for the exchange of information between the contractor and DOE;

     c. Assures that instructions to the contractor are within the terms of the contract;

     d. Assures compliance by the contractor with the technical, safety, and administrative requirements of the contract;

     e. Participates in the formulating of, and approving, plans and schedules;

     f. Arranges for contacts between the construction contractor, other participants, and appropriate staff, as required;

g. Assures continuity in performance and information exchange among the project team participants; and

h. Initiates to the contracting officer procurement request packages for contract modifications.

2. Project Engineer or Construction Engineer. This engineer is the individual responsible for construction projects for which a project manager is not assigned. He or she performs within well defined responsibilities established by the Head of the Field Element. Specific responsibilities vary depending upon the field office management method. He or she may be assigned as the contracting officer's technical representative.

1.11 *Civil/structural engineering personnel shall demonstrate a working level knowledge of the principles associated with surveying, grading, drainage, and paving.*

Supporting Knowledge and/or Skills

a. Discuss the basics of surveying practices.

The surveyor's business is measurement[1]. The three basic types of measurements the surveyor concerns himself with are angles, distances and elevations. These measurements must be made within a set of ethical standards determined by the profession. The surveyor uses a tape or an electronic device to measure distance, a transit or theodolite to measure angles, and a level and rod to measure elevations. In the process of obtaining these measurements, the survey must plan to achieve both economy and accuracy in the survey. Economy and accuracy are usually competing elements in the overall process of surveying. It is the surveyor's job to maximize both for the requirement of each project.

b. Read and interpret a site contour map.

Contours are the most common method of showing topography on a 2-dimensional map[1]. Contours show a constant elevation. Usually each fifth contour, called an index contour, is darker and heavier, and is numbered to show elevation. The contours between index contours are divided equally and represent equal elevation increments. A few comments on reading contour lines:

- Equally spaced lines show a uniform slope;
- Lines very close together show steep slopes, even cliffs;
- Cross or "X" is usually accompanied by an elevation, showing the highest elevation on a peak or hill;
- Series of contours that abruptly bend uphill and then return are usually associated with a stream, river, or some past water flow;
- Contour lines of different elevations rarely cross (an overhanging cliff). Lines of equal elevation can cross and represents a geographic structure called a saddle;
- Contours are perpendicular to the direction of water flow; and,
- Contours are stopped at the edge of a building

c. Given field notes and data, draw a contour map.

The field notes and the survey data will yield an X-Y plot of all the data points[1]. Identify these points with an elevation. Determine what contour intervals will yield an effective map, with the contours not to cluttered but not so far apart that they skip important features. Next, begin measuring between adjacent points, interpolate the position of the contour, and place a small mark. Continue this process between all adjacent points, then use a flexible straight edge to connect points of like elevation.

There are some software programs that exist that are much more efficient than doing this by hand. The programs typically take a spreadsheet input file and convert the points to a contour map in a computer aided drafting program.

d. Read and interpret a site plan drawing (old contour, new contour).

A site plan shows what the site looks like from above, and includes contours.[2] The site plan shows the boundary streets, property lines, easements, rights-of-ways, size and type of utilities, compass directions, trees, streams, lakes, swamps, benchmarks, transportation routes, zoning, jurisdictional requirements.

Boundaries are represented by a line consisting of a long and two short dashes. Contours are continuous lines. Utilities are dashed lines. Building lines are solid lines.

Old contour lines show the condition of the site before construction. The new contour lines show the site after final grading has been completed, taking into account drainage patterns on site.

e. Define the following terms as they relate to horizontal curves:

- Point of intersection (PI): A curve is initially laid out by showing the two lines that the curve is to connect. Where these two lines meet is called the Point of Intersection;[1]
- Point of tangency (PT): The end of the curve is called the Point of Tangency. This is the point where the curve ends and the tangent resumes; and,
- Point of curvature (PC): The beginning of the curve is called the Point of Curvature. This is the point where the line intersects the curve.

f. Using field data, prepare a site grading plan.

To the engineer assigned to create a site grading plan, the same rules apply to the grading plan as to creating a contour map. The primary concern to the engineer, however, is location of the contours to provide adequate drainage away from building structures. Drainage away from buildings prevents unwanted shrinking and swelling of the soil surrounding the buildings. The engineer grades the contours on the map to cause the flow of run off to drain towards storm sewers. The engineer must also give special attention to the grading of parking lots, as pavement allows no seepage, whereas soil can store run off, thus not causing as much flooding as pavement and concrete. Secondary to the site grading process, balance of the cuts and fills will prevent the contractor from extra costs associated with fill purchase or waste disposal.

g. Define, compare, and contrast the following terms:

- Balance and cut-and-fill
- Shrink and swell

Balance and cut and fill

Cut is a term used to describe material that will have to be removed on a project. Fill describes an earthen embankment, usually one that must be installed on a project.

Balance describes the equilibrium situation on an earth-moving project where the volume of the material excavated will equal the material required to fill the rest of the project.[3]

The designer of an excavation project strives to balance the cuts and the fills. Balancing is important as shortages in fill material can be expensive, either from a borrow pit or purchased from off site. Even more rarely does an engineer want more cuts than fills, as this creates a disposal problem, unless the material has a market value.

Shrink and swell

Swell describes the increase in volume of a material as it is excavated. Shrink describes the volume loss as the material is placed and compacted. They are both used in earth moving projects and are usually not reciprocal. The swell factor is usually greater than one, as voids are added during excavation. The shrinkage factor is usually smaller than one, and describes the soil after placement and some compactive effort applied.

h. Discuss the characteristics of rigid and flexible pavement.

A rigid pavement is designed primarily on the basis of its resistance to bending and, essentially, portland cement concrete is the sole type of pavement in this category.[4] Concrete pavement design requires a knowledge of the mechanics of reinforced concrete and the mechanics and stability of the material used as a sub-grade to the rigid pavement. The rigid pavement acts like a series of small bridges carrying the load of the vehicle, and the pavement must be designed accordingly. Rigid pavements must also account for thermal qualities of the material through the use of expansion joints, much more so than flexible pavements.

A flexible pavement consists of a relatively thin wearing surface supported by layers of compacted subgrade. The strength of the pavement is derived from the distribution of the load over the subgrade through the subbase, base, and surface courses rather than the carrying capacity of the pavement as a whole. The most common threat to flexible pavement is the combination of heavy rains, long periods of cold with an abrupt spring can cause frost heaves, or buckling of the pavement at the wearing surface.

i. Discuss the hydraulics associated with drainage to include:

- **Open channel flow**

The primary difference between flow in closed conduits and flow in open channels is that in open channels there is a free surface at atmospheric pressure, whereas in closed-conduit flow, there is no free surface[5]. Open channel flow can be an extremely complex phenomenon to describe. The depth of the channel, configuration of the sides of the channel, material lining the channel and changes in the direction of flow all contribute to the velocity, and ultimately, the quantity of flow through a cross section. Gravity is usually the primary driving force in an open channel situation.

In any drainage situation, the maximum rainfall expected in the given life span of the project should be determined. With total inflow now determined, the drainage engineer will determine all divide lines on the project. These lines will separate the areas that will receive the predetermined estimate of rainfall. With these areas and rainfall estimates, the flow on a project can be determined using open channel flow equations. The drainage system at the outlet of the project needs to be designed to at least this criteria of flow quantity, sometimes another channel flow problem.

- **Flood zone determination**

In a flood zone determination, much like the drainage situation, the engineer must estimate the total flow input to the drainage system[6]. With this estimate complete, the engineer must then create a cross section of the flood plane, including river, banks, foliage, rocks, etc. The engineer then creates imaginary vertical surfaces which divide the main channel and the overbank areas. That part of the flood plane which is being flooded is called the overbank area[5]. Each of these areas need to be correlated to a manning's number, which vary based on the frictional resistance of the material in the overbank area. For example, a flooded area of short crops yields a manning's number of 0.035, whereas a flood in dense willows yields a manning's number of 0.150. Since flow is inversely proportional to the resistance (manning's number), then more resistance the higher the flooding region, since the quantity of flow must remain approximately the same. This engineer then repeats this analysis at intervals along the main channel and then the engineer plots the height data on a contour map. The contour map graphically shows the zone that a flood of given magnitude affects.

[1] McCormac, Jack C., "Surveying Fundamentals," 2nd ed., Prentice-Hall, Englewood Cliffs, NJ, 1991.
[2] Merritt, Frederick S. and Ambrose, James, "Building Engineering and Systems Design," 2nd ed., Van Nostrand Reinhold, New York, NY, 1990.
[3] Ringwald, Richard C., "Means Heavy Construction Handbook," 1st ed., Construction Publishers & Consultants, Kingston, MA, 1993.
[4] Woods, Kenneth B., "Highway Engineering Handbook," 1st ed., McGraw-Hill Book Company, New York, NY, 1960.
[5] Roberson, John A., Crowe, Clayton T., "Engineering Fluid Mechanics," 5th ed., Houghton Mifflin Company, Boston, MA, 1993.
[6] Potter, Merle, C., "Principles and Practice of Civil Engineering," 1st ed., Great Lakes Press, Okemos, MI, 1994.

1.12 Civil/structural engineering personnel shall demonstrate a working level knowledge of the principles and concepts of structural analysis.

Supporting Knowledge and/or Skills

a. Identify and discuss the various methods of structural analysis.

Frames and trusses are analyzed using methods dependent upon whether the structure is statically determinate or indeterminate. Analysis is simplest for structures in one dimension, and is considerably complicated for three-dimensional structures.

A statically determinate frame is one in which the number of unknown reactions and member forces is the same as the number of available equilibrium equations. Statically determinate structures can be analyzed using the equations of statics. The structure is analyzed while in a state of equilibrium using the following scalar equations of equilibrium:

$$\sum F_H = 0 , \qquad \sum F_V = 0 , \qquad \sum M = 0 .$$

Relationships of bending moments, axial forces and shear forces are then analyzed and determined using appropriate sign conventions.

The equations of equilibrium may then be applied systematically through several methods of statically determinate analysis. The method of joints assumes that no connection may support a moment, and that all forces, compression and tensile, are aligned along the axis of the members. With these geometric constraints and knowledge of the moments the forces in the sturcture may be analyzed joint by joint using the horizontal and vertical summations listed above. The method of joints requires a systematic analysis of all of the joints in the structure. In some cases, not all of the member forces are of interest. If only a few member forces are required then the structure can be fractured through the section where the member force are of interest. Then, replace the rest of the structure with forces aligned geometrically along the axis of each sectioned member. This method is called the method of sections and it requires the same basic assumptions as the method of joints. Overall static summation forces can then be used to determine the unknown sectional forces.

A statically indeterminate frame is one in which the number of unknown reactions and member forces is greater than the number of available equilibrium equations. The degree of static indeterminancy is often found as the analysis is being performed using a sound practice of applying free-body diagrams and determining the number of unknown forces and reactions. The major methods of indeterminate structural analysis are the force method (flexibility method) and the displacement (stiffness method). Refer to Section 1.12d for more discussion on these methods.

b. Discuss the purpose of shear and moment diagrams.

Shear and moment diagrams can be used to evaluate the shear value and moment imposed at any location on a structural member. The diagrams can be used to determine the maximum shear loading and moment loading that are imposed on a member at any point along the member. This information can then be utilized to design the member cross section needed to support the loads imposed. At a vertical section through a member in equilibrium, external forces on one side of the section are balanced by internal forces. The unbalanced external vertical force at the section is called the shear. Since the moment diagram is an integration of the shear diagram, the slope of the moment diagram at any point is equal to the shear at that point.

c. Discuss the fundamentals of the finite element method of structural analysis.

The finite element method of structural analysis where the body or structure to be analyzed is modeled as an assembly of finite elements interconnected at specified nodal points, is an extension of the matrix displacement method. The difference between the two methods is the choice of the stiffness matrix, permitting the inclusion of different types of elements into the analysis. As a result, the solution is greatly facilitated through convergence using a computer. The accuracy of the stiffness matrices can be distinctly improved by the introduction of additional nodes along the length of a member or in the plane of a planar element, depending on the degree of accuracy needed. Even though this analysis can be done manually, it would be quite tedious and cumbersome. The use of computers has significantly increased the viability of this approach.

d. Discuss the differences between the flexibility and stiffness methods of structural analysis.

The major methods of structural analysis are the force method (flexibility method) and the displacement method (stiffness method). In the force method, deformation is consistent and the moment forces are the primary unknowns. In the displacement method, the displacements are the primary unknowns. The numerical application of the displacement method in which the desired moments, shears, or stresses are obtained by a method of successive approximations suitable for longhand computation in called the moment distribution method. The method lends itself to simple physical interpretation.

e. Discuss the differences between the elastic and plastic methods of structural analysis.

In elastic analysis, sometimes known as allowable stress or working stress analysis, the design is based upon resisting a fraction of the minimum specified yield stress. The load imposed for design purposes is a summation of estimated working or service loads. In plastic analysis, sometimes known as collapse analysis, the design is based upon summing the imposed loads that would result in collapse failure and then applying a safety or over-capacity factor to decrease the acceptable stress value.

1.13 Civil/structural engineering personnel shall demonstrate a working level knowledge of the fundamentals of reinforced concrete design.

Supporting Knowledge and/or Skills

a. Identify and discuss the minimum building code requirements for reinforced concrete as contained in the American Concrete Institute (ACI) document ACI-318, Building Code Requirements for Reinforced Concrete.

The requirements contained in ACI-318 cover the full spectrum of reinforced concrete construction from design through placement. The code specifies minimum requirements for structural evaluation and design, materials standards, quality control of mixing process, formwork design and installation, reinforcement design and installation, concrete placement, environmental parameters, and testing.

b. Discuss the longitudinal and shear reinforcement requirements for beam design.

Unlike idealized structural materials such as steel, concrete has a much lower tensile strength than compressive strength. Therefore, concrete beams must be reinforced in those areas of the beam that would be subjected to tensile stresses caused by shear and/or longitudinal loading. Tensile stresses as a result of shear loading are maximum at the neutral surface and tensile stresses as a result of bending that impose longitudinal loading are a maximum at the outer surface. As a result, reinforcement requirements have to be evaluated at the neutral surface and the outer surface most subject to tension. The vector sum of the shear and bending tensile stresses act at an angle to the horizontal and is known as diagonal tension. It is necessary to provide reinforcement in concrete beams to resist this diagonal tension.

c. Discuss the basics of the following:

- Cast-in-place concrete
- Pre-stressed concrete
- Post-tension concrete
- Tilt-up concrete
- Structure design

Cast-in-place concrete is utilized for those installations where custom form work is constructed. Pre-cast concrete is utilized for those installations that lend themselves to standard shapes that can be assembly line manufactured such as blocks, beams, columns, and slabs. The advantages of pre-cast shapes are lower cost, enhanced quality control of the process, and increased safety by virtue of minimizing work site labor hours.

Pre-stressed concrete structures can be fabricated by two methods; pre-tensioned or post-tensioned. In pre-tensioning, the tendons are tensioned by a suitable means such as jacking and then concrete is placed around the tendons and allowed to cure. In post-tensioning, the concrete is cast and allowed to cure. Next, tendons are inserted in voids in the cast concrete, tensioned by a suitable means such as jacking, and the ends are clamped or crimped. The advantages of pre-stressed concrete structural elements are reduced cost and improved quality control of the construction process by virtue of assemble line type fabrication. Also, for a given amount of material, the load carrying capability is significantly increased in that the initial loading of the pre-stressed element simply relieves the pre-load and the element has remaining the capability to carry a load equal to that which a non-pre-stressed element would be capable of supporting.

Post-tension concrete. See also Pre-stressed concrete (above). In post-tensioning, the concrete is first cast and allowed to cure. The concrete is cast with preformed voids of ducts in which bonded or unbonded tendons are then elongated (tensioned). Bonded construction entails the filling of tendon ducts with a grout after tensioning; unbonded construction entails wrapping the greased tendons with asphalt impregnated paper or plastic.

In **tilt-up construction**, typically a wall section is formed up and cast in the horizontal plane. After the slab has cured sufficiently, it is lifted and tilted in to position. The casting process is reasonably straight forward except for bond prevention between the slab and the surface upon which it is cast. Bond breakers can be liquids, canvas, impregnated paper, felt, or other similar materials. Some bond breaking materials can be quite difficult to remove and/or can stain the tilt-up slab. If surface finish is a major concern, special emphasis must be given to the bond breaking method and the lower form material.

In developing a **structural design**, the initial evaluation is one of relative cost associated with the different types of structural building materials available (i.e. concrete, pre-stressed concrete, steel frame with concrete shell, steel sheath on steel frame, etc.). Costs can be influenced by material availability, local labor rates, environmental conditions, and owner preference among other things. After this basic decision has been made, the design engineer must fully understand the use of the structure and the environmental demands on the structure. Whether the structure is for residential, commercial, or industrial use, the loads imposed on the structure must be determined and the design performed to address these loads. Aside from the obvious need to access the mass of the structure and equipment, environmental factors such as wind, seismic, flooding must be accounted for. When all these factors are identified and evaluated, then the engineer can proceed with the detailed calculations as prescribed by the various applicable codes and standards.

1.14 *Civil/structural engineering personnel shall demonstrate a working level knowledge of the principles of structural steel design.*

Supporting Knowledge and/or Skills

a. Identify and discuss the minimum building code requirements for structural steel as contained in the following American Institute of Steel Construction (AISC) documents:

- AISC M011, Manual of Steel Construction
- AISC N690, Nuclear Facilities: Steel Safety-Related Structures for Design, Fabrication, and Erection

When contractual documents do not contain specific provisions to the contrary, existing trade practices are considered to be incorporated into the relationships between the parties to a contract. As in any industry, trade practices have developed among those involved in the purchase, design, fabrication, and erection of structural steel. AISC M011, the *Manual of Steel Construction*, provides a listing of the properties of structural shapes and provides design parameters for steel structures.

In a similar manner, AISC N690 provides properties and design parameters for steel structures in the nuclear industry. In general, the design process incorporates enhanced rigor and increased documentation for quality assurance purposes in nuclear facilities.

b. Explain the difference between allowable stress design (ASD) and load resistance factor design (LRFD).

With allowable stress design, the working or service loads are combined for the various members of a particular structure to obtain the maximum loads. Then members are selected such that their computed elastic stresses (when the maximum loads are applied) do not exceed certain allowable values. In structural steel design, these stresses usually are given as being equal to some percentage of the yield stress.

Load resistance factor design is based on a limit states philosophy. The term limit state is used to describe a condition at which a structure or some part of that structure ceases to perform its intended function. There are actually two categories of limit states, strength and serviceability. Strength limit states are based on the safety or load carrying capacity of structures and include plastic strengths, buckling, fracture, fatigue, overturning and so on. Serviceability limit states refer to the performance of structures under normal service loads and are concerned with the uses and/or occupancy of structures including such items as excessive deflections, slipping, vibrations, cracking and deterioration.

c. ***Given data, analyze a steel beam and determine its compliance with American Institute of Steel Construction requirements.***

Example 1.14-1

A roof system with W16 X 40 sections spaced 9 ft on-center is to be used to support a dead (D) load of 40 psf, a roof live (L) or snow (S) or rain ® load of 30 psf, and a wind (W) load of 20 psf. Compute the governing critical factored load.

Solution

D = 40 + (9)(40) lbs/ft = 400 lbs/ft
L = 0
L *or* S *or* R = (9)(30) = 270 lbs/ft
W = (9)(20) = 180 lbs/ft

Substituting into the LRFD load combination expressions

U = (1.4)(400) = 560 lbs/ft (1)
U = (1.2)(400) + 0 + (0.5)(270) = 615 lbs/ft (2)
U = (1.2)(400) + (1.6)(270) + (0.8)(180) = 1056 lbs/ft (3)
U = (1.2)(400) +(1.3)(180) + (.5)(270) = 849 lbs/ft (4)
U = (1.2)(400) + 0 + (0.2)(270) = 534 lbs/ft (5)
U = (0.9)(400) ± (1.3)(180) = 594 or 126 lbs/ft (6)

Governing factored loads = 1056 lbs/ft

d. ***Given data for a steel column, analyze the column and determine its compliance with American Institute of Steel Construction requirements.***

Example 1.14-2

The various axial loads for a building column have been computed according to the applicable building code with the following results: dead load = 200 k, load from roof = 50 k (roof live load), live load from floors (has been reduced as applicable for large floor area and multistory columns) = 250 k, wind = 80 k, and earthquake = 60 k. Determine the critical design (u) load using the six LRFD load combinations.

Solution

U = (1.4)(200) = 280 k (1)
U = (1.2)(200) + (1.6)(250 + (0.5)(50) = 665 k (2)
U = (1.2)(200) + (1.6)(50) + (0.5)(250) = 445 k (3(a))
U = (1.2)(200) + (1.6)(50) + (0.8)(80) = 384 k (3(b))
U = (1.2)(200) + (1.3)(80) + (0.5)(250) + (0.5)(50) = 494 k (4)
U = (1.2)(200) ± (1.0)(60) + (0.5)(250) = 425 or 305 k (5)
U = (0.9)(200) ± (1.3)(80) = 284 or 76 k (6(a))

$$U = (0.9)(200) \pm (1.0)(60) = 240 \text{ or } 120 \text{ k} \qquad (6(b))$$

The critical factored load combination or design strength required for this column is 665 k as determined by LRFD Formula 2. It will be noted that the results of Formulas 5 and 6 do not indicate an uplift problem.

e. Sketch and explain the stress-strain curve for steel.

The largest stress for which Hooke’s law applies or the highest point on the straight-line portion of the stress-strain diagram is the *proportional limit.* The largest stress that a material can withstand without being permanently deformed is called the *elastic limit.* This value is seldom actually measured and for most engineering materials including structural steel is synonymous with the proportional limit. For this reason, the term *proportional elastic limit* is sometimes used.

The stress at which there is a decided increase in the elongation or strain without a corresponding increase in stress is said to be the *yield* stress. It is the first point on the stress-strain diagram where a tangent to the curve is horizontal. The yield stress is probably the most important property of steel to the designer, as so many design procedures are based on this value. Beyond the yield stress there is a range in which a considerable increase in strain occurs without increase in stress. The strain that occurs before the yield stress is referred to as the *elastic strain*; the strain that occurs after the yield stress, with no increase in stress, is referred to as the *plastic strain.* Plastic strains are usually from 10 to 15 times the elastic strains.

Following the plastic strain there is a range in which additional stress is necessary to produce additional strain. This is called *strain-hardening*. This portion of the diagram is not too important to today’s designer because the strains are so large. A familiar stress-strain diagram for mild or low-carbon structural steel is shown in Figure 1.14-1. Only the initial part of the curve is shown here because of the great deformation which occurs before failure. At failure in the mild steels the total strains are from 150 to 200 times the elastic strains. The curve will actually continue up to its maximum stress value and then “tail off” before failure. A sharp reduction in the cross section of the member takes place (called “necking”) followed by failure.

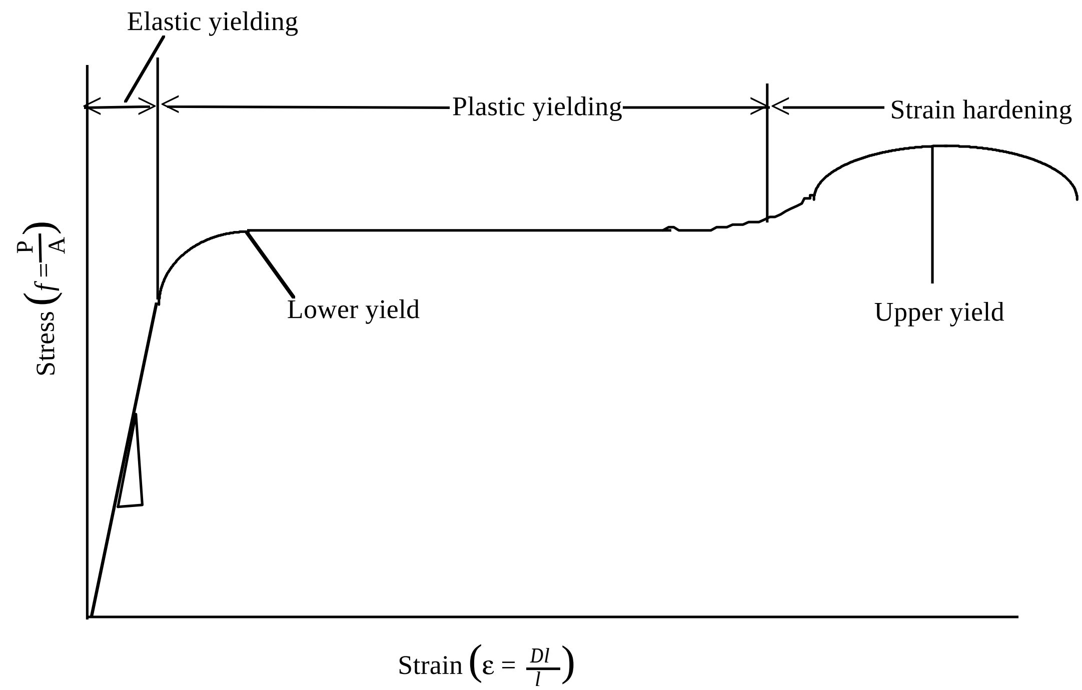

Figure 1.14-1 Typical stress-strain diagram for a mild or low-carbon structural steel at room temperature.

f. Define the following:

- Minimum edge distance
- Unbraced length
- Beam bearing plate
- Web crippling

Minimum edge distance is the distance from the centerline of a bolt hole or slot to the edge of a plate. This length, multiplied by the thickness of the plate, defines the edge distance. The minimum edge distance is defined by the following equation whose fundamental basis lies in factoring the ultimate force applied on the bolt by 60%:

$$Xe = 2 \cdot d;$$

Where

Xe is the minimum edge distance
d is the diameter of the bolt

The minimum edge distance can be reduced if the bolt shear strength used is less than the shear strength of the plate, as bolt failure will proceed shear failure in the plate.

Unbraced length is the distance in a member between points that are braced.

Beam bearing plate is a plate of steel placed upon a masonry surface that supports the end of a steel beam restraining vertical movement but allowing horizontal movement.

Web crippling is the failure of the web of a member near a concentrated force.

g. Given data and the appropriate equations, calculate the following for a steel member:

- Average shear stress
- Parabolic shear stress
- Bending stress
- Axial stress
- Torsional shear stress

Equations for calculating the parameters listed above will vary depending upon the loading profile imposed upon the member (uniform loading with simple end supports, single point loading with simple supports, etc.).

h. List the causes of buckling of load bearing columns.

When a beam or column is not fully braced laterally, it may fail due to buckling laterally about the weaker axis between the points of lateral bracing. This will occur even though the beam is loaded so that it supposedly will bend about the stronger axis. The beam will initially bend about the stronger axis until a certain critical moment is reached. At that time it will buckle laterally about its weaker axis. As it bends laterally the tension in the other flange will try to keep the beam straight. As a result the buckling of the beam will be a combination of lateral bending and lateral torsional buckling (or torsion) of the beam cross section.

The stress-strain response of steel in compression is very much the same as the response of steel in tension. The major difference in response occurs with yielding and strain hardening. Whereas the tension specimen will experience decreasing cross sectional area as it lengthens, eventually necking down to a fracture condition, the compression specimen will experience an increasing cross sectional area as its length shortens, eventually leading to a barrel-shaped specimen that simply squashes outward, not fracturing at all, but failing be deforming excessively in a condition called compression flange buckling. If the compression specimen were longer than 2 or 3 diameters, lateral deformations under applied force could prohibit development of the compression flange mode, and failure would occur as the specimen bends away from the line of compressive forces at each end of the column. The tendency for a compressed bar to bend away from the loading line is called compression buckling.

Compression buckling will occur at stress levels that become smaller and smaller as the effective length of the member increases. The effective length of a member is the distance between points of contraflexure as the column buckles. Slenderness is a measure of the effective length together with the cross sectional size. A typical limit stress versus slenderness is used to design columns. Slenderness is the ratio of kL/r between the effective length kL and radius of gyration. K is a theoretical value as determined by the physical constraints on each end of the column. The more degrees of freedom on each end of the column,. the higher the value of k (can be as high as 2). The fewer degrees of freedom on each end, the lower the value of k (can be as low as .5).

Analysis is performed on columns to determine the minimum axial compressive load for which a column will experience lateral deflections. Analysis is most accurate for long slender columns. For these columns, the slenderness ratio (the column length divided by the radius of gyration about the axis of bending).is large. A pivot-ended column, commonly used analysis approximation, is supported such that the bending moment and lateral movement are zero at the ends. Free-body diagrams are used to illustrate the forces acting on the column. The compressive load that would cause buckling, referred to as the Euler Buckling Load, is then calculated using the Euler equation. This equation uses the moment of inertia, slenderness ratio, the Modulus of Elasticity to calculate the buckling load.

i. Describe the following types of connections:

- Friction
- Bearing
- Tension
- Rigid
- Non-rigid
- Semi-rigid

A friction connection is a bolted connection designed in a situation where the smallest slip of the surfaces would be unacceptable. Essentially, the quality of the bolts must be increased and the bolts tightened to an extent where the clamping pressure generated by such bolts is near the yield strength of the shank of the bolt.

A bearing connection is a connection where the load is constrained in one dimension and sometimes allowed to move in directions to allow for the differential thermal qualities between a steel structure and one of another material. A bearing connection is primarily used to distribute the loads from a steel member into a masonry or concrete portion of the structure. The primary concern in bearing plate design is the size of the bearing plate, to distribute the high loads found in a steel member effectively into lower loads typically allowed in a masonry or concrete structure.

A tension connection is a connection where the load is applied in tension along the axis of the bolts thus utilizing the strongest qualities of the bolt. This is opposed to a combined tension-shear connection, where the components of the load on the connection do not lie parallel to the axis of the line of bolts, thus inducing a shear stress in the bolts.

A rigid or continuous frame connection is a connection that, for evaluation purposes, is considered to maintain the original angle between members under load. Connections of this type may be used for tall buildings in which wind resistance is developed. The connection, either riveted, bolted or welded, provides continuity between the members of the building frame.

A non-rigid or simple connection is a connection that, for evaluation purposes, is considered to be flexible and free to rotate. These types of connections also exist practically in a truss type environment, whereby the connections are pins and cannot support a moment

A semi-rigid connection is a connection that, for evaluation purposes, is considered to offer resistance to angular change that is between a rigid and a simple connection. A true semi-rigid connection may have significant moment reductions from the rigid and simple connections, reducing calculation requirements. Use of this connection and its analysis, however, is often discouraged since it requires a method of analysis which falls in between analysis for simple beams and for a statically indeterminate structure with rigid joints. This results in connections in a structure which have varying percentages of moment restraint.

<u>References</u>

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1.15 Civil/structural engineering personnel shall demonstrate a working level knowledge of the principles and characteristics of natural phenomena as related to structures.

General The impacts of natural phenomena are considered on a facility-by-facility basis, using a graded approach dependent on the facility’s [i.e. the system, structure, or component, (SSC’s)] function. A SSC will be assigned a “Performance Category” reflecting risk to workers, the public, or the environment that will occur if it is damaged or destroyed. Each Performance Category has an associated “Performance Goal”, which is the allowable probability for SSC failure to occur. In the discussion of impacts of natural phenomena hazards (NPHs) and their mitigation, the information will in general apply to the highest Performance Category (Performance Category 4, with a Performance Goal of loss of ability to maintain confinement at a probability of 10^{-5}), with lower Performance Categories subject to less stringent requirements.

Supporting Knowledge and/or Skills

a. Discuss the impact on facilities and the mitigating factors associated with the following hazards:

- **Flooding**

From a design basis standpoint, the design criteria for a SSC impacted by flooding are water damage, hydrostatic pressure on walls and roofs, and dynamic effects of erosion (shear), wind-wave action, and debris loads/impacts.

In a flooding event, the impact on facilities are the results of submergence, hydrostatic loads, and dynamic loads. Submergence principally impacts the internal components of a facility, causing loss of electrical power, failure of containment of radioactive or hazardous materials; it may render the facility unfit for future operation. Foundation settling may also occur. Hydrostatic loads must be considered in design of exterior walls located below the design basis flood level. Dynamic loads must be considered in the impact of wind-waves, ice flows, and debris, as well as erosion of foundations and protective dikes and levees.

For new facilities, the easiest method to avoid a flooding event is to select a site above the design basis flood level, based on analysis of the probability of an initiating event: river flooding, dam or dike failure, storm surge, etc. To mitigate the impact of local precipitation, both sites and facilities should be designed for adequate drainage, and roofs constructed with sufficient structural strength to support water ponded to level of a secondary roof drainage system. For existing sites with a significant risk of flooding, dikes, levees, and drainage features may be implemented; emergency action plans, flood recognition and early warning systems may allow operational response to flood events.

For example, flooding is not considered a credible event at the Rocky Flats Site, due to the location, terrain, and meteorology, although inadequate roof and site storm drainage have resulted in local water damage in the past.

- **Wind**

  From a design basis standpoint, the design criteria impacted by sustained wind are pressure on walls and roofs, and the impact of wind-driven missiles.

  In a extreme wind event, the impact on facilities from the pressures generated by the wind are lateral loading on structural surfaces and damage at corners and eaves (outward pressure on the downstream surface). In the event that the surface is breached (e.g. a door or window is broken, or a wind-driven missile penetrates), then interior pressure can develop causing other wall and roof surfaces (as well as interior walls) to be blown outward. Wind pressure may also cause problems with ventilation containment system pressure reversals.

  The impact on facilities from wind-driven missiles must be calculated based on an assumed condition. For Performance Category 4 SSCs, the assumed missile criteria is a 2X4 timber plank, 15 lb. at 50 mph (horizontal), maximum height of 50 ft above ground.

  Features of facilities commonly used to mitigate impacts of extreme wind are additional structural supports, additional anchoring for external features, cross-bracing on walls and ceilings, and reinforced concrete external walls. Dynamic analysis (vibration response spectra) may be required for taller, thinner SSCs.

  For example, the design basis event for sustained wind at the Rocky Flats Site is 161 miles/hour. Missile criteria is bounded by the tornado missile.

- **Tornado**

  From a design basis standpoint, the design criteria impacted by a tornado are pressure on walls and roofs, and the impact of wind-driven missiles.

  In a tornado event, one impact on facilities from the pressures generated by the tornado winds are lateral loading on structural surfaces. This can generally be considered as translational force with no rotational component (the sum of the tornado rotational and translational velocities). Atmospheric pressure change (APC) between the vortex center and the radius of maximum wind can exert an outward force (suction) on walls and roofs causing other wall and roof surfaces (as well as interior walls) to be blown outward. APC may also cause problems with ventilation containment systems.

The impact on facilities from wind-driven missiles must be calculated based on an assumed condition. For Performance Category 4 SSCs, the assumed missile criteria are: a 2X4 timber plank, 15 lb. at 150 mph (horizontal), maximum height of 200 ft above ground, 100 mph (vertical); a 3 in. diameter steel pipe, 75 lb. at 75 mph (horizontal), maximum height of 100 ft above ground, 50 mph (vertical); and a tumbling 3000 lb. automobile, 25 mph.

Features of facilities commonly used to mitigate impacts of tornadoes are additional structural supports, cross-bracing on walls and ceilings, and reinforced concrete external walls. For “squat” facilities, static analysis is typically satisfactory, but dynamic analysis is required for taller, thinner SSCs.

For example, the design basis event for sustained wind at the Rocky Flats Site is 161 miles/hour; no supplemental velocity is provided for tornadoes. Missile criteria are given above. For most plutonium facilities at the Rocky Flats Site, the structural features needed to meet seismic requirements bound those needed to meet wind/tornado requirements.

- **Earthquake and/or other seismic events on facilities**

From a design basis standpoint, the design criteria impacted by a seismic event are the structural features necessary to prevent the collapse, loss of containment, or falling over of SSCs. Key differences are the impact of seismic requirements throughout the structure and the need for dynamic analysis of SSCs.

In a seismic event, the initiating event is lateral and vertical acceleration on a SSC. The probability/severity of seismic events are very location-specific, being much more frequent in areas of major faults. Within a general area, variation in immediate geology and foundation design will result in differing impacts on different SSCs. The impact of the seismic vibration or acceleration will be amplified from the movement of soil, with the amplification being generally less for SSCs with foundations closer to or attached to bedrock, and with larger and more rigid foundations. Within a larger structure amplification and damping of seismic vibrations will also occur, so SSCs located within that structure must be analyzed base on the local vibration spectra. Impact on the facility will be collapse of members and rocking and rolling of components. Interaction between SSCs must be considered from structural failing and falling, proximity, flexibility of lines an attached cables, flooding or exposure to fluids from ruptured vessels, piping systems and dams, and effects of seismically-induced fires.

Features of facilities commonly used to mitigate impacts of seismic events are evaluation of event probability and seismic dynamic modeling and analysis, which generally results in strengthening, stiffening, and buttressing structures or designs, and modifying foundations and siting of larger facilities. The general approach is to use a probabilistic basis to select the design load, and then use deterministic approaches to evaluate the permissible response levels and perform design calculations. For SSCs within a larger structure, method to mitigate seismic impacts are seismic qualification of purchased components, analysis of anchoring requirements, additional points of attachment, and other means of dampening modes of vibration. Single point failures must be analyzed. For existing facilities analyses must be performed as to their seismic risk. Remedying unsatisfactory conditions will be based on relative risk and intended length of future service.

Operational mitigation of seismic risk is provided by the facility safety analysis report, which will bound facility risks and conditions and set requirements on facility procedures, classification of components, allowable inventory, and similar operational parameters. Additional quality assurance of components and peer review of designs and modifications is required to assure as-built and ongoing facility risk.

For example, the design basis earthquake at the Rocky Flats Site is nominally 0.24 g for Performance Category 4 SSCs; however, values for all facilities must be analyzed based on the requirements of DOE-STD-1023-95. The 94-3 Implementation Plan sets an ‘Evaluation Basis Earthquake” for Building 371 at 0.25 g peak ground acceleration.

b. ***Describe the safety measures and design features commonly used as safeguards against natural hazards.***

Safety measures and design features used to mitigate the effects of floods are:

- Siting of the SSC above the design basis flood;
- Dikes and levees to keep elevated waters away for the facility;
- Development of emergency implementation plans and early warning systems;
- Design of sites with adequate drainage for abnormal levels of precipitation;
- Design of secondary drainage systems to preclude problems from pluggage of primary drainage systems (roofs and local areas of sites); and,
- Sealing and hardening of SSC to prevent water damage.

Safety measures and design features used to mitigate the effects of sustained winds are:

- Strengthening of surfaces of facilities to account for lateral and vertical wind loading;
- Design of facilities for internal pressures generated by extreme winds;
- Facility cladding and roofing to mitigate surface damage;
- Design for wind-driven missile damage; and,
- Emergency plans and early warning systems to warn of and prepare for severe storms.

Safety measures and design features used to mitigate the effects of tornadoes are:

- Strengthening of surfaces of facilities to account for lateral and vertical wind loading, and APC conditions;
- Design of facilities for internal pressures generated by extreme winds;
- Facility cladding and roofing to mitigate surface damage;
- Design for wind-driven missile damage; and,
- Emergency plans and early warning systems to warn of and prepare for severe storms.

Safety measures and design features used to mitigate the effects of earthquakes are:

- Siting of facilities in areas of low seismic activity;
- Modeling, designing and modifying facilities to withstand appropriate seismic loads;
- Developing safety analyses and adherence to operational requirements to assure that facilities operate within an adequate safety envelope; and,
- Equipment qualifications, installation, internal design, and quality control to assure component performance.

c. ***Discuss the requirements related to earthquake load design that are stipulated in Department of Energy (DOE) Order 6430.1A, General Design Criteria, for Department facilities used for radioactive material handling, processing, or storage.***

The General Design Criteria specifies the following design requirements for new facilities handling, processing, or storing radioactive material:

Section 0111-2.4	Wind loading shall be based on UCRL 53526, Rev.1 wind speed and missile parameters;
Section 0111-2.5	Tornado loads shall be based on UCRL 53526, Rev.1 wind speed and missile parameters;
Section 0111-2.7	Earthquake loads shall be based on UCRL 53582 requirements. Site specific hazards models shall be developed. Earthquake load design shall be according to procedures contained in UCRL 15910 (now superseded by DOE-STD-1020-94). Independent reviews of seismic design will be made for higher-risk facilities;
Section 0111-99	Requirements to those above are delineated for Nonreactor Nuclear Facilities; and,
Section 200-1.1	Natural Hazards, including wind, hurricane, tornado, and seismic activity are required to be considered in the siting of facilities.

d. ***Describe the use of the following University of California Research Laboratory (UCRL) documents in determining the design requirements for structural wind, tornado, and earthquake loading:***

- **UCRL 15910, Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena**

  This document reports the efforts of the DOE and the DOE Natural Phenomena Hazards Panel to develop uniform design and evaluation guidelines for protection against NPH at DOE sites throughout the United States. It has been superseded by DOE-STD-1020-94. DOE 6430.1A references the guidelines included in this report as an acceptable approach for design evaluation of DOE facilities for the effects of NPH. UCRL-15910 provides earthquake ground acceleration, wind speed, tornado wind speed and other effects, and flood level corresponding to the design basis earthquake (DBE), design basis wind (DBW), design basis tornado (DBT), and design basis flood (DBFL) as described in Order 6430.1A. Integrated with these natural phenomena loadings, UCRL-15910 provides recommended response evaluation methods and acceptable criteria in order to achieve acceptably low probabilities of facility damage due to natural phenomena.

  The design and evaluation guidelines presented in this report control the level of conservatism introduced in the design/evaluation process such that earthquake, wind, and flood hazards are treated on a reasonably consistent and uniform basis. These guidelines also seek to ensure that the level of conservatism in design/evaluation is appropriate for facility characteristics such as importance, cost, and hazards to people on and off site and to the environment. For each NPH covered, these guidelines generally consist of the following:

  - ◊ Usage categories and performance goals;
  - ◊ Hazard probability from which NPH loading on structures, equipment and systems is developed; and,
  - ◊ Recommended design and evaluation procedures to evaluate response to hazard loads and criteria to assess whether or not computed response is possible.

  The report evaluates the likelihood of occurrence of NPH at each site. Probabilistic hazard models are available for earthquake, extreme wind/tornado, and flood. Site organizations are encouraged to develop site-specific hazard models utilizing the most recent information and techniques available.

  Performance goals andnatural hazard levels are expressed in probabilistic terms, and design and evaluation procedures are presented in deterministic terms. Design/evaluation procedures conform closely to common standard practices so that the procedures will be easily understood by most engineers. Performance goals are expressed in terms of structure or equipment damage to the extent that: (1) the facility cannot function; (2) the facility would need to be replaced; (3) personnel are endangered.

- **UCRL 53526, Natural Phenomena Hazards Modeling Project, Extreme Wind/Tornado Hazard Models for Department of Energy Sites**

  This document reports on wind hazard models which were developed by the Lawerence Livermore National Laboratory (LLNL) for the DOE Office of Nuclear Safety. This work was part of a three-part effort to establish uniform building design criteria for seismic and wind hazards at DOE sites throughout the United States. This report summarizes the final wind/tornado hazard models recommended for each site and the methodology used to develop these models. The information contained in this document has been incorporated into DOE-STD-1020-94 which supersedes the UCRL report.

- **UCRL 53582, Natural Phenomena Hazards Modeling Project, Seismic Hazard Models for Department of Energy Sites**

  This document reports on seismic hazard models which were developed by the Lawerence Livermore National Laboratory (LLNL) for the DOE Office of Nuclear Safety. This work was part of a three-part effort to establish uniform building design criteria for seismic and wind hazards at DOE sites throughout the United States. This report summarizes the final seismic hazard models and response spectra recommended for each site and the methodology used to develop these models. The information contained in this document has been incorporated into DOE-STD-1020-94 which supersedes the UCRL report.

1.16 Civil/structural engineering personnel shall demonstrate a working level knowledge of seismic analysis fundamentals.

Supporting Knowledge and/or Skills

a. Given data characterizing the stiffness and mass, evaluate the frequency and modal shapes.

Stiffness, mass, and frequency response are are related by the second order differential equation[1]

$$+ \qquad =$$

The solution of this equation is in the following form:

$$= \qquad w + f$$

Where A is the amplitude of the oscillation, ω is the frequency, and ϕ is the phase relationship.

b. Explain the significance of a design response spectra.

A design response spectra is a statistical tool used to analyze a site and generates an input for the general approach for seismic design and evaluation. Inherent in the spectra are key components such as the magnitude of the controlling earthquakes, distance estimates, and ground motion studies. A complete description of the development and use of the design response spectra is given in DOE-STD-1023-95.

c. Discuss how floor response spectra are evaluated.

Using the peak ground acceleration, anchor a median standardized spectral shape such as the median spectral shape as defined in NUREG/CR-0098, or deterministic site specific derived median spectral shape. In all cases, the spectral shape should be consistent with the rock or soil site conditions at the site in question. The resulting response spectra should be compared to that being used to establish the Design Basis Earthquake at each site. If the DBE spectral shape is lower than NUREG/CR-0098 spectral shape, it is recommended that a site specific spectral shape be developed.

d. Discuss the role of damping and how it affects structural response.

Damping is a linear, velocity dependent component of the response of a structure and always occurs in the direction opposite of the motion of the structure. Damping exists in any structural response, but the degree of damping can be varied. The degree of damping desired can change based on dynamic strength of the components of the structure and the strength of the connections. Damping is one component of the dynamic response of a structure to applied, non-conservative loads.[2]

e. Discuss the time-history and modal response methods of analysis.

The time history method of analysis is a mathematical development for each strucure.[3] The ordinary differential equations are developed and the solutions are found for the structure. If the input forcing function is harmonic, a closed form analytical solution can be found. If the forcing function is an arbitrary input, the solution is not always closed form. On a single degree of freedom system, it is advantageous to model the structure with the time-history method. On single degree of freedom systems it is usually more efficient to compute the time response using numerical procedures of time integration and differential equation solving. Once the time-history method is chosen, there are many numerical methods for solving these problems.

The modal response method of analysis is an experimental study of structural dynamics. Modal response analysis is, in effect, the process of constructing a mathematical model to describe the dynamic properties of a structure based on test data. Once the model matches the theoretical mathematical model to an allowable level of accuracy, the mathematical model can then be subjected to new loads and situations, and the responses can be predicted from the analysis. The modal model is defined as a set of natural frequencies with corresponding vibration mode shapes and modal damping factors. It is important to remember that this solution always describes the various ways in which the structure is capable of vibrating naturally, without any external forcing or excitation, so these are called the normal, or natural modes of the structure.

The modal testing system is advantageous where the structure cannot be modeled accuately with a mathematical model. Also, through experimental testing, complex responses that a mathematical model may have simplified remain in the output, thus increasing correlation with the actual structure. The modal response method generally requires more time and effort than a mathematical model, and should be reserved for the more complex structures.

f. Discuss the importance of ductility and how it is achieved in:

- A reinforced concrete structure.
- A steel structure.

The property of a material by which it can withstand extensive deformation without failure under high tensile stresses is called ductility.[4] When a mild or low-carbon steel member is being tested in tension, a considerable reduction in cross section and a large amount of elongation will occur at the point of failure before the actual fracture occurs. A material that does not have this property is generally unacceptable and is probably hard and brittle and might break if subjected to a sudden shock. Steel ductility is a function of the steel forming process.

In structural steel members under normal loads, high stress concentations develop at various points. The ductile nature of the usual structural steel members enables them to yield locally at these points. thus preventing premature failures. A further advantage of ductile structures is that when overloaded their large deflections give visible evidence of impending failure, jokingly referred to as “running time.”

Reinforced concrete ductility is more a function of design than material properties.[5] Reinforced concrete works on a basic principle, the compressive strength of the concrete is utilize for the compressive zone in a member, and the tensile strength of steel is used in the tensile zone of the structure. The design of the beam can be handled in three ways:

1. Balanced section. The steel begins yielding just as the concrete reaches the point of crushing.
2. Over reinforced section. Failure occurs by initial crushing of the concrete, as the steel is strong enough for the loads applied. This usually results in a violent failure situation.
3. Under-reinforced section. This is achieved by under designing slightly the reinforcement in the tensile zone of the concrete. Because the steel begings yielding first, the ductile properties of steel may be taken advantage of during a slow failure.

g. Discuss the parameters that determine when soil structure interaction effects are significant.

Soil structure interaction analyses shall be carried out when required to ascertain the influence of the interaction of the structure and the surrounding soil on the response of the structure to the defined site free field ground motions.[6] Soil structure interaction effects are more significant for heavy and/or embedded structures. Criteria for conducting soil structure interaction analyses are provided in DOE-STD-1020-94.

The effects of soil structure interaction should be considered for structures, systems and components in Performace Category 3 and shall be performed in Performance Category 4. Soil structure interaction analyses shall use the design free-field ground motion as input. The required soil parameters to obtain and analyze are depth, soil type, density, shear modulus, damping, and their variations with strain levels for each of the soil layers. Internal friction angle, cohesive strength, and the over-consolidation ratio are required for a non-linear analysis. A wide range of the shear moduli should be examined to obtain the most conservative design.

Dynamic soils properties can vary significantly depending on whether soil layers are saturated. For soil structure interaction analysis, unsaturated soil properties should be used for soil layers above the normal water table unless the site conditions indicate that additional soil saturation occurs frequently or for long durations.

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[1] Inman, Daniel J., "*Engineering Vibration*," 1st ed., Prentice-Hall, Engelwood Cliffs, NJ, 1994.
[2] "*Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*," DOE-STD-1020-94.
[3] Ewins, D. J., "Modal Testing: Theory and Practice," 1st ed., Research Studies Press, Ltd., Letchworth, England, 1984.
[4] McCormac, Jack C., "*Structural Steel Design*," 2nd ed., Harper Collins College Publishers, New York, NY, 1995.
[5] Nawy, Edward G., "*Reinforced Concrete*," 2nd ed., Prentice-Hall, Englewood Cliffs, NJ, 1990.
[6] "*Natural Phenomena Hazards Characterization Criteria*," DOE-STD-1022-94

1.19 *Civil/structural engineering personnel shall demonstrate the ability to analyze potable and waste water treatment systems.*

Supporting Knowledge and/or Skills

a. Discuss the following methods of waste water treatment:

- Primary
- Secondary
- Tertiary

Primary Waste Water Treatment – Primary treatment begins with simple screening. Screening removes large floating objects such as rags, sticks, and whatever else that might damage the pumps or clog small pipes. Screens typically consist of parallel steel bars spaced anywhere between 2 and 7 cm apart, possibly followed by a wire mesh screen with smaller openings. One way to avoid the problem of disposal for materials collected on screens is to use a comminuter, which grinds coarse materials small enough to be left in the wastewater flow.

After screening, the wastewater passes into a grit chamber where it is held for a few minutes. The detention time must be long enough to allow sand, grit, and other heavy material to settle out but short enough to prevent lighter, organic materials to settle. By collecting only the heavier materials, the disposal problem is simplified, since those materials are usually non-offensive and, after washing, can be usually disposed of in a municipal landfill.

From the grit chamber, the sewage passes to a primary settling tank, also known as a sedimentation basin or a clarifier, where the flow speed is reduced sufficiently to allow most of the suspended solids to settle out by gravity. Detention times of about 2 to 3 hours are typical, resulting in the removal of from 50 to 65 percent of the suspended solids and 25 to 40 percent of the biological oxygen demand (BOD). Primary settling tanks are either round or rectangular. the solids that settle, called primary sludge or raw sludge, are removed for further processing, as is the grease and scum that floats to the top of the tanks.

If only primary treatment is to be used, the effluent is chlorinated to destroy bacteria and help control odors. Then it is released.

Secondary (Biological) Treatment – The main purpose of secondary treatment is to provide BOD removal beyond what is achievable by simple sedimentation. There are three commonly used approaches, all of which take advantage of the ability of microorganisms to convert organic wastes into stabilized, low-energy compounds. Two of these approaches, the trickling filter and the activated sludge process, sequentially follow primary treatment. The third, oxidation ponds, or lagoons, can provide equivalent results without preliminary treatment.

A trickling filter consists of a rotating distribution arm that sprays liquid wastewater over a circular bed of fist size rocks or other coarse materials. The spaces between the rocks allow air to circulate easily so that aerobic conditions can be maintained. The size of such openings is such that there is no actual filtering that takes place. Instead, the individual rocks in the bed are covered by a layer of biological slime that adsorbs and consumes the wastes trickling through the bed. the slime consists mainly of bacterial, but it may also include fungi, algae, protozoa, worms, insect larvae, and snails. The accumulating slime periodically slides off of individual rocks and is collected at the bottom of the filter, along with the treated wastewater, and passes on to the secondary settling tank where it is removed. There is also a provision for returning some of the effluent from the filter back into the incoming flow. This recycling not only enables more effluent organic removal, but also keeps the biological slime from drying out and dying during low flow conditions.

If ordinary rocks are used in the bed of a trickling filter, structural problems caused by their weight tend to restrict the bed depth to about 3 meters. This makes it necessary for the beds to be quite large. Diameters as great as 60 meters are not uncommon. However, plastic media are becoming increasingly popular as a replacement for rocks, since in the same volume they can be designed to achieve greater surface areas for slime growth, and their lightness allows much deeper beds. This allows equivalent treatment to rock beds, but with much smaller land area requirements. They can also be designed to be less prone to plugging by the accumulating slime, and slightly higher rates of BOD removal are possible. These filters, made of plastic media, are sometimes referred to as biological towers.

A variation of a trickling filter is a rotating biological contactor (RBC). An RBC consists of a series of closely spaced, circular, plastic disks, that are typically 3.6 meters in diameter and attached to a rotating horizontal shaft. The bottom 40 percent of each disk is submerged in a tank containing the waste water to be treated. The biomass film that grows on the surface of the disks moves into and out of the waste water as the RBC rotates. While the microorganisms are submerged in the waste water, they adsorb organics; while they are rotated out of the waste water, they are supplied with needed oxygen. By placing modular RBC units in series, treatment levels that exceed conventional secondary treatment can be achieved. These devices are easier to operate under varying load conditions than trickling filters, since it is easier to keep the solid medium wet at all times.

Activated sludge processes cost less to build, are less temperature sensitive, and remove more BOD than trickling filters. The key biological unit in the process is the aeration tank, which receives effluent from the primary clarifier. It also receives a mass of recycled biological organisms from the secondary settling tank, known as activated sludge. to maintain aerobic conditions, air or oxygen is pumped into the tank and the mixture is kept thoroughly agitated. After about 6 to 8 hours of agitation, the waste water (mixed liquor) flows into the secondary settling tank where the solids, mostly bacterial masses, are separated from the liquid by subsidence. A portion of those solids is returned to the aeration tank to maintain the proper bacterial population there, while the remainder must be processed and disposed of.

Activated sludge tanks can take up considerably less land area than trickling filters with equivalent performance. They do, however, require more energy for pumps and blowers, therefore they have higher operating costs.

Once the sludge has been removed from the waste water, liquid effluent is usually released into a nearby body of water. The traditional method of sludge processing utilizes anaerobic digestion. Anaerobic digestion is slower than aerobic digestion, but has the advantage that only a small percentage of wastes are converted into new bacterial cells. Instead, most of the organics are converted into carbon dioxide and methane gas. In the first phase, complex organics such as fats, proteins, and carbohydrates are biologically converted into simpler organic materials, mostly fatty acids. The bacteria that perform this conversion are commonly referred to as acid formers. They are relatively tolerant to changes in temperature and pH, and they grow much faster than the methane formers that carry out the second stage of digestion.

Methane-forming bacteria slowly convert the organic acids into carbon dioxide, methane, and other stable end products. These bacteria are very sensitive to temperature, pH, toxins, and oxygen. If their environmental conditions are not just right, the rate at which they convert organic acids to methane slows, and organic acids begin to accumulate, dropping pH. A positive feedback loop can be established where the acid formers continue to produce acid, while the methane formers, experiencing lower and lower pH, become more and more inhibited. When this occurs, the digester is said to have gone sour, and massive doses of lime may be required to bring it back to operational status.

Most treatment plants utilizing anaerobic digestion for sludge stabilization use a two-stage digester. Sludge in the first stage is thoroughly mixed and heated to increase the rate of digestion. Typical retention times are between 10 and 15 days. The second stage tank is neither heated nor mixed and is likely to have a floating cover to accommodate the varying amount of gas being stored. Stratification occurs in the second stage, which allows a certain amount of separation of liquids (supernatant) and solids, as well as the accumulation of gas. The supernatant is returned to the main treatment plant for further BOD removal, and the settled sludge is removed, dewatered, and disposed of. The gas produced in the digester is about 60 percent methane.

Digested sludge removed from the second stage of the anaerobic digester is still mostly liquid. The solids have been well digested, so there is little odor. The most popular way of dewatering has been to pump the sludge onto large sludge drying beds where evaporation and seepage remove the water. Other methods include the use of vacuum filters, filter presses, centrifuges, or incinerators. The digested and dewatered sludge is potentially useful as a soil conditioner, but much of the time it is trucked away and disposed of in a landfill.

<u>Oxidation ponds</u>are large, shallow ponds, typically 1 to 2 meters deep, where raw or partially treated sewage is decomposed by microorganisms. The ponds can be designed to maintain aerobic conditions throughout, but more often the decomposition taking place

near the surface is aerobic, while that near the bottom is anaerobic. Such ponds, having a mix of aerobic and anaerobic conditions, are called facultative ponds. In ponds, the oxygen required for aerobic decomposition is derived from surface aeration and algal photosynthesis; deeper ponds, called lagoons, are mechanically aerated.

Oxidation ponds can be designed to provide complete treatment to raw sewage, but they require a good deal of space (1 acre for 100 people).

Ponds are easy to build and manage, they accommodate large fluctuations in flow, and they can provide treatment that approaches that of conventional biological systems but at a much lower cost. The effluent, however, may contain undesirable concentrations of algae, and especially in the winter when less oxygen is liberated by photosynthesis, they may produce unpleasant odors. Used alone, they also have the disadvantage that the effluent may not meet the EPA secondary treatment requirements for BODs and suspended solids. Oxidation ponds are also used to augment secondary treatment, in which case they are often called polishing ponds.

Tertiary (Advanced) Waste Water Treatment– Anything that follows conventional primary and biological treatment is considered to be advanced treatment. Advanced treatment is designed to remove nitrogen and phosphorus, as well as removing various toxic substances, such as metals. The toxic substance removal falls under hazardous waste treatment technologies, including, but not limited to, the following:

- Physical treatment: sedimentation, adsorption, aeration, reverse osmosis, ion exchange, and electrodialysis;
- Chemical treatment: neutralization, chemical precipitation, chemical reduction-oxidation;
- Biological treatment: aqueous waste treatment, in-situ biodegradation;
- Waste incineration; and,
- Land disposal: surface impoundments, underground injection.

For further information on these removal processes, please refer to the referenced text for this section.[1]

b. Given waste water chemistry data, analyze the data and determine the treatment of the effluent necessary for compliance with the National Pollutant Discharge Elimination System (NPDES) requirements with the following parameters as a minimum:

- Biological oxygen demand (BOD);
- Chemical oxygen demand (COD);
- Total dissolved solids (TDS); and,
- pH

For any given waste water treatment system, the waste water chemistry data must be analyzed based on several parameters set forth in the NPDES permit for that system. An example of these parameters are given in Table 1.19-1 below.

Biological Oxygen Demand (BOD) -- The BOD is the amount of oxygen required by microorganisms to oxidize organic wastes aerobically. The total amount of oxygen that will be required for complete biodegradation of a sample of waste would require an extended period of time (several weeks), therefore it has become standard practice to measure and report the oxygen demand over a period of 5 days, which is the total amount of oxygen consumed by microorganisms during the first 5 days of degradation (BOD_5).

Chemical Oxygen Demand (COD) -- The COD is a measured quantity that does not depend either on the ability of microorganisms to degrade the waste or on knowledge of the particular substance in question. In a COD test, a strong chemical oxidizing agent is used to oxidize the organics rather than relying on microorganisms to do the job. The COD test is much quicker than a BOD test, taking only a matter of hours. However, it does not distinguish between the oxygen demand that will actually be felt in a natural environment due to biodegradation, and the chemical oxidation of inert organic matter. Nor does it provide any information on the rate at which actual biodegradation will take place. The measured value of COD is higher than BOD, though for easily biodegradable matter the two will be quite similar. The COD test is sometimes used as a way to estimate the ultimate BOD.

Total Dissolved Solids (TDS) -- TDS is a commonly used measure of salinity in water. Fresh water can be considered to be water with less than 1500 mg/l TDS; drinking water has a recommended maximum contaminant level for TDS of 500 mg/l. TDS is sometimes referred to as Total Suspended Solids (TSS). As can be seen by the amount recommended in the sample NPDES permit, the allowed amount of 30 mg/l is much lower than the acceptable drinking water level recommendations.

pH -- pH is the way to express the acidity or alkalinity of the water. Without going into the chemistry of determining pH, a neutral solution has a pH of 7, with high acidity being less than 2 and high alkalinity being greater than 12.5. The table below specifies that the pH of the waste water treatment effluent should stay in the range of 6 to 9.

The water treatment plant that is required to meet the discharge limits given in Table 1.19-1 uses primary waste water treatment consisting of screening, sand and grit settling, and TDS removal by settling in a clarifier. This would be sufficient to achieve the TDS (or TSS) limit. The activated sludge process (secondary waste water treatment) is used to meet the BOD requirements, as well as removing nitrogen (as nitrates) and phosphorus (by adding lime). The addition of lime assists in the elevation of the pH, if needed. Although chlorine is added to kill pathogens present from fecal coliform, residual chlorine must be kept to a minimum. Reverse osmosis is used as an advanced treatment method for removing chromium.

Table 1.19-1: Sample NPDES Permit Requirements

		Effluent Concentration	
Parameter	30-Day Avg. (mg/l)	7-Day Avg. (mg/l)	Daily Max. (mg/l)
BOD_5, mg/l	10 (a)	N/A	25 (d)
Total Suspended Solids, mg/l	30 (a)	45 (b)	N/A
Fecal Coliform, No./100 ml	200 (c)	400 (c)	N/A
Nitrates (as N), mg/l	10 (a)	20 (b)	N/A
Total Residual Chlorine, mg/l	N/A	N/A	0.5 (d)
Total Chromium, mg/l	0.05 (a)	N/A	0.10 (d)
Total Phosphorus (as P), mg/l	8 (a)	N/A	12 (d)
pH, units	Shall remain between 6.0 and 9.0 (d, e)	Shall remain between 6.0 and 9.0 (d, e)	Shall remain between 6.0 and 9.0 (d, e)

(a) This limitation shall be determined by the arithmetic mean of a minimum of 3 consecutive samples taken on separate weeks in a 30-day period.
(b) This limitation shall be determined by the arithmetic mean of a minimum of 3 consecutive samples taken on separate weeks in a 7-day period.
(c) Averages for Fecal Coliforms shall be determined by the geometric mean of a minimum of 3 consecutive grab samples taken during separate weeks in a 30-day period for the 30-day average, and during separate days in a 7-day period for the 7-day average.
(d) Any single analysis and/or measurement beyond this limitation shall be considered a violation of the conditions of this permit.
(e) The pH may go as high as 10.0 if it is documented that any pH above 9.0 was due to algal activity and high pH wastes from the sewage treatment plant.

c. Given water chemistry data, analyze the data and determine the treatment needed to bring it into drinking water standards.

The Safe Drinking Water Act (SDWA) of 1974 was established to provide safe drinking water to the public. Both primary and secondary drinking water standards have been set by EPA regulations. These standards represent the Maximum Contaminant Level (MCL) allowable, and consist of numerical criteria for specified contaminants. A list of contaminants with their respective MCLs and best available technologies (BAT) are in the table below.

Contaminant	**MCL (in parts per million)**	**BAT [1]**
Alachlor	0.002	GAC
Aldicarb	0.003	GAC
Aldicarb sulfone	0.003	GAC
Aldicarb sulfoxide	0.003	GAC
Atrazine	0.003	GAC
Carbonfuran	0.04	GAC
Chlordane	0.002	GAC;PTA
Dibromochloroprophane	0.0002	GAC
2,4- D	0.07	GAC
Endin	0.0002	GAC;PTA
Ethylene dibromide	0.00005	GAC;PTA
Heptachlor	0.0004	GAC
Heptachlor epoxide	0.0002	GAC
Lindane	0.0002	GAC
Methoxychlor	0.04	GAC
PCBs	0.0005	GAC
Pentachlorophenol	0.001	GAC
Toxaphene	0.003	GAC
2, 4 5-TAP (Silvex)	0.05	GAC
Acrylamide	0.005% dosed at 20 mg/l	Limit use
Epichlorohydrin	0.01% dosed at 20 mg/l	Limit use
Arsenic	0/05	RO;IE
Asbestos	7 MFL (millions of fibers per liter >10µ in length)	C/F;CF; DMF; CC
Barium	1	IE;LS;RO; ED
Cadmium	0.005	C/F;RO;LS; IE
Chromium	0.05	C/F;RO;LS; IE
Fluoride	4.0	RO;IE
Lead	0.015	RO;IE
Mercury	0.002	GAC;LS; C/F;RO
Nitrate	10	IE;RO;EDR
Nitrite	1	IE;RO
Selenium	0.05	EDR;C/F; AA;LS;RO
Coliforms	0	Disinfection
Giardia	0	Disinfection
HPC	0	Disinfection
Legionetta	0	Disinfection
Virus	0	Disinfection

Turbidity	1 NTU (Neflametric Turbidity Unit)	DMF;GAC
Gross alpha particle	15pCi/l	RO;IE;C/F;EV
Gross beta particle	4 mrem/yr	RO;IE;C/F;EV
Contaminant (Cont.)	**MCL (in parts per million)**	**BAT [1]**
Radium 226 and 228	5 pCi/l	RO;IE;C/F;EV
Benzene	0.005	GAC;PTA
Carbon tetrachloride	0.005	GAC;PTA
p-Dichlorobenzene	0.075	GAC;PTA
o-Dichlorobenzene	0.06	GAC;PTA
1,2-Dichloroethane	0.005	GAC;PTA
1,1-Dichloroethane	0.007	GAC;PTA
cis-1,2-Dichloroethylene	0.07	GAC;PTA
trans-1,2-Dichloroethylene	0.1	GAC;PTA
1,2-Dichloropropane	0.005	GAC;PTA
Ethylbenzene	0.7	GAC;PTA
Monochlorobenzene	0.1	GAC;PTA
Styrene	0.1	GAC;PTA
Tetrachloroethylene	0.005	GAC;PTA
Toluene	1	GAC;PTA
Trichloroethylene	0.005	GAC;PTA
Vinyl chloride	0.002	PTA
Xylenes	10	GAC;PTA
Total trichalomethanes	0.10	GAC;PTA

[1] AA = Activated Alumina
CC = Corrosion Control
C/F = Coagulation/Filtration
DF = Direct Filtration
DMF = Diatomite Filtration
EV = Evaporation
GAC = Granular Activated Carbon
IE = Ion Exchange
LS = Lime Softening
PTA = Packed Tower Aeration
RO = Reverse Osmosis

The typical treatment systems for bringing raw water up to drinking water quality might include the following processes:

- Screening to remove relatively large floating and suspended debris.

- The removal of suspended particles from water may be achieved by charge reduction, bridging, or bonding of particles followed by sedimentation. Coagulation means charge reduction. Classical coagulation physics assumes that colloidial particles in suspension have a negative charge. The colloids remain in the suspension because of the normal mechanical forces applied cannot overcome the electrostatic repulsion forces. The addition of the appropriate cation provides a means for reduction of the charge. The Shultz-Hardy rule states that the destabilization of a colloid and coagulation effectiveness increases with charge so that monovalent, divalent and trivalent species should be effective approximately in the ratio of 1:100:1000. In most practical systems, the Shultz-Hardy rule is violated because the electrolytes are indifferent. Inorganic compounds added to the water react with the solution electrolyte, form complexes and precipitates. Hence, coagulation power for monovalent, divalent and trivalent species is taken at 1:60:700. The important result of the Shultz-Hardy rule is its implication in the selection of the coagulant. The characteristics of the coagulant must be such that it is non-toxic, high degree of density and is insoluable in a pH range that is neutral. Coagulants include alum, ferric chloride and ferric sulfate. Alkalinity is defined as the sum of all titratable bases down to a pH of about 4.5. It is a measure of the buffer capacity. The definintion of akalinity is:

$$\text{Alkalinity} = [HCO_3] + 2[CO_3] + [OH] - [H]$$

- Where [] referes to the concentrations in moles/L. below a pH of 8.3 it may be assumed that all of the alkalinity is in the bicarbonate form (HCO_3). By convention, alkalinity analysis are reported in units of mg/L as $CaCO_3$. The conventional coagulants form precipitates if the pH of the water is in the correct range. In hard water, aluminum is insoluable in the pH range of 5 to 8. In soft water, the effective range of pH is 5 to 7. The iron salts are insoluable in the nominal pH range of 4 to 11. Alum and the iron salts are acid forming when dissolved in water. Thus, a coagulant's effectiveness may be self-inhibiting if insufficient alkalinity is present. The reactions for alum and ferric chloride when alkalinity is present may be summarized as:

$$Al_2(SO_4)_3 \cdot 14H_2O + 6HCO_3 \Leftrightarrow 2Al(OH)_3 + 6CO_2 + 14H_2O + 3SO_4$$
$$FeCl_3 + 3HCO_3 \Leftrightarrow Fe(OH)_3 + 3CO_2 + 3Cl$$

- When the Alkalinity is destroyed, the reactions are:

$$Al_2(SO_4)_3 \cdot 14H_2O \Leftrightarrow 2Al(OH)_3 + 3H_2SO_4 + 8H_2O$$
$$FeCl_3 + 3H_2O \Leftrightarrow Fe(OH)_3 + 3HCl$$

The selection of the appropriate coagulant and the determinination of the appropriate dose are best described with jar tests and an economic evaluation of the alternatives.

- Flocculation is the process of joining two or more particles together to form a floc. This may be accomplished by a variety of mechanisms: mechanical stirring to induce collisions, enmeshment in the precipitate formed by the coagulant, bridging between particles by polymers. Common design practice is to provide a flocculation basin divided into three compartments. The velocity gradient is tapered to reduce the G value from the first to last compartment. For axial flow impellers, the rule of thumb used in design are that the impeller diameter is between 0.2 and 0.5 times the width of the chamber and that the maximum impeller diameter is about 3m. For paddle flocculators, the periphial velocity of the paddle blade relative to that of the water is taken as approximatele 3/4 of the periphery blade velocity. The total blade area on the horizontal shaft should not exceed 15 to 20 percent of the total basin cross sectional area. Typical values for G and Gt_o are given in the following table:

Type	G, s^{-1}	Gt_o
Low-turbidity removal coagulation	20-70	60,000 to 200,000
High-turbidity removal coagulation	10-150	90,000 to 180,000
Softening 10% Solids	130-200	200,000 to 250,000

- The relationship between the power imparted to the liquid and the design of impeller mixers is expressed by Rushton's equation:

  $P=Kn^3D_i^5p$

  Where:
  P is power in W,
  K is the impeller constant
  n is rotational speed, r/s
  D_i is impeller diameter, m
  p is the density of the liquid, kg/m^3

  For paddle flocculators, the equation changes to:

  $P=C_DAp(v^3/2)$

  Where:
  C_D is the coefficient of drag
  A is the paddle blade area perpindicular to flow
  v is the relative velocity of the fluid

  Hardness is defined as the sum of all of the polyvalent cations. For practical purposes, total hardness is taken as the sum of the calcium and magnesium ions in mg/L as $CaCO_3$. Because in the difference in reaction chemistry, total hardness is divided into two subcategories: carbonate hardness and noncarbonate hardness. Carbonate hardness is defined as the amount of hardness equal to the alkalinity or total hardness whichever is less. Noncarbonate hardness os the total hardness in excess of the total alkalinity. If the alkalinity is equal to or exceeds the total hardness, there is no noncarbonate hardness.

To remove calcium, the precipitate calcium carbonate must be formed. The carbonate may come from naturally occuring carbonate in the form of bicarbonate (HCO_3) or may be added as sodium carbonate. Significant removal of $CaCO_3$ is achieved when the pH is about 9.6 - 10.8. Magnesium hydroxide must be formed to remove magnesium. The hydroxide is normally provided in the form of slaked lime. Significant removal of magnesium hydroxide is achieved when the pH is above about 10.8 - 11.5.

The primary reactions for softening are summarized as follows:

$$CO_2+Ca(OH)_2 \Leftrightarrow CaCO_3+H_20$$
$$Ca+2HCO_3+ Ca(OH)_2 \Leftrightarrow 2CaCO_3+2H_2O$$
$$Mg+2HCO_3+Ca(OH)_2 \Leftrightarrow MgCO_3+CaCO_3+2H_20$$
$$MgCO_3+Ca(OH)_2 \Leftrightarrow Mg(OH)_2+CaCO_3$$
$$Ca+Na_2CO_3 \Leftrightarrow CaCO_3+2Na$$
$$Mg+Ca(OH)_2 \Leftrightarrow Mg(OH)_2+Ca$$
$$Ca+Na_2CO_3 \Leftrightarrow CaCO_3+2Na$$

- Sedimentation in which the flow is slowed enough so that gravity will cause the floc to settle;
- Sludge processing where the mixture of solids and liquids collected from the settling tank are dewatered and disposed of; and,
- Disinfection of the liquid effluent to ensure the water is free of harmful pathogens.

Other processes include:

- Physical processes: comminution, grit removal, equalization, flotation, filtration, air stripping, reverse osmosis, distillation, ammonia stripping, and microscreening;
- Biological processes: activated sludge, rotating biological contractors, extended aeration, trickling filters, land application, surface impoundments, and oxidation ditches;
- Chemical processes: carbon absorption, chemical precipitation, ion exchange, oxidation, chlorination, and thermal treatment; and,
- Sludge treatment processes: gravity thickening, centrifugation, dissolved air flotation, aerobic digestion, chlorine oxidation, lime stabilization, heat treatment, incineration, land application, vacuum filtration, filter presses, and composting.

[1] *Introduction to Environmental Engineering and Science*, Gilbert M. Masters, Prentice-Hall, 1991.

1.20 Civil/structural engineering personnel shall demonstrate a familiarity level knowledge of the various computer applications used in civil engineering.

Supporting Knowledge and/or Skills

a. Identify and discuss at least one of the major computer codes used in structural analysis.

A popular code in use by structural engineers is FORTRAN 90.[1] FORTRAN has some powerful routines involving matrix manipulation and analysis, which make it well suited for structural analysis. Also, input files can be rather simple, not requiring exact formatting. FORTRAN is also common, cheap, routinely taught in classrooms, and easy to learn.

b. Describe the applications of computer-aided design (CAD) as it relates to civil/structural engineering design functions (e.g., grading, drainage, paving, piping network analysis, structural analysis).

Structural analysis – There exist sophisticated structural analysis and design programs, such as STAAD-III, which can take an input of a stick structure, various design loads, types of fasteners, and even material type including wood, reinforced concrete, steel, aluminum, etc. and yield an output which includes sectional requirements, reinforcing data, and some joint properties. Also on the market are several Finite Element Analysis programs. There are also 3D animation packages for the construction of structures. These programs include JSpace and the Construction Simulation Toolkit in conjunction with Bechtel's Walkthru program.

Piping network analysis – Another helpful set of computer aided design packages assist the engineer to develop piping systems. A piping network analysis is an iterative process between flow and pipe resistance. The same programs can also be used for traffic flow in a city street network. These programs include Lindo, Lingo and Gino.

Grading, drainage and paving – There are various aftermarket programs for the most popular drawing packages. These programs, such as AdCadd and QuickDirt can generate drainage, grading and paving plans with ease. COGO is a program that integrates survey geometry and AutoCad. Eagle Point's RoadCalc program analyzes various roadway designs and corresponding costs and layouts. Final products include plans, profiles, cross sections, mass balance diagrams and even virtual simulations. Eagle Point's Watershed Modeling program handles storms, land use, slope values, travel times and computes water storage, stage discharge relationships, and a scenario modeler.

The engineer must not rely solely on these packages. These programs are intended only to augment calculations completed by the engineer. Use of these programs require that the engineer have a sound background in the disciplines that are being automated.

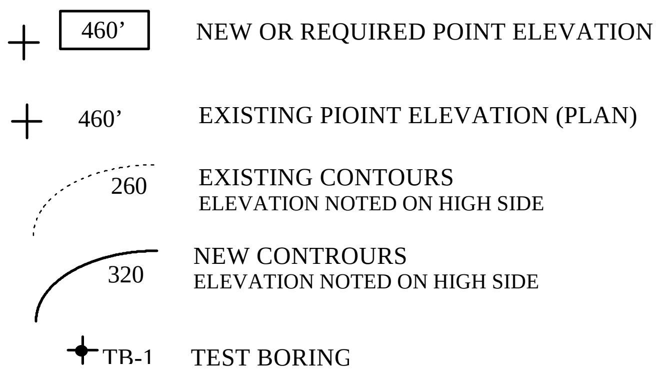
[1] Vanegas, Jorge, Chinowsky, Paul, *Computing in Civil Engineering* 1st ed., American Society of Civil Engineers, New York, NY, 1996.

1.21 Civil/structural engineering personnel shall demonstrate the ability to use civil engineering plans and drawings.

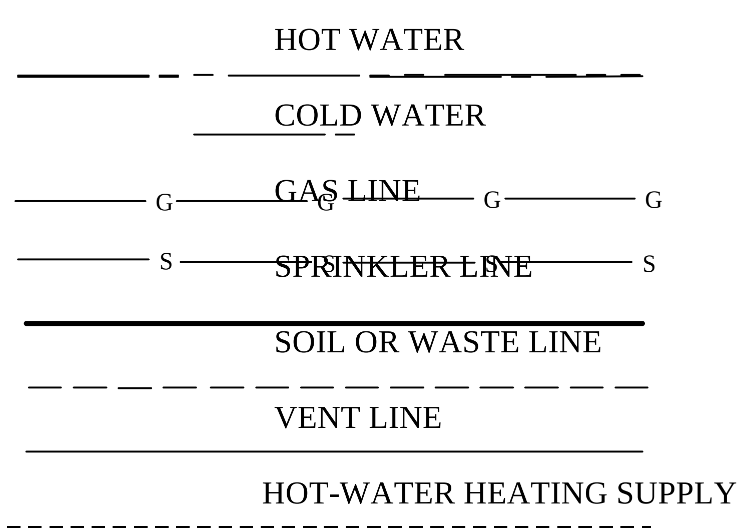
This is a demonstration requirement.

Drawings are miniature as well as picture-like representations of a building or object. Because of the relatively small size of drawings, many components cannot be shown on some drawings exactly as they look. Consequently, designers have to use a special kind of graphic language to indicate the many items that they cannot actually picture. This language employs symbols to represent materials and components. The following tables are examples of basic symbology for the listed topics. To accurately interpret the symbology of a drawing, check the legends and tables on the controlled drawings that are applicable to the project, since different architects and software packages may use unique symbology.

a. Given a site plan, identify elevations, soil and rock probes, and contours.



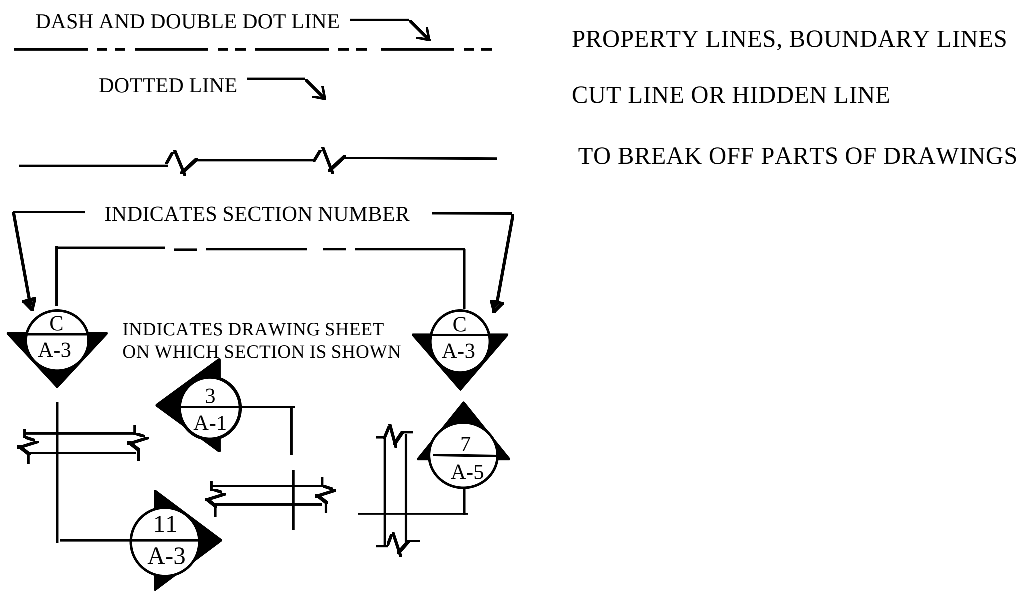
b. Given a utility plan, identify sewer, potable water, gas, power, and fire-suppression lines.



HOT-WATER HEATING RETURN

c. ***Given architectural or structural plans or details, describe the key features in the design and explain the symbols used.***

- Basic architecture



d. ***Given a specification package and a set of drawings, analyze the drawings to verify that the specifications have been met.***

This is a demonstration skill.

Check the drawing against the specifications. Check dimensions on all elevations and plans, sizes, shape, locations (if applicable), materials, assemblies, equipment, fabrication, finishing, tolerances, and any other information called out on the drawings and specifications.

2.1 Civil/structural engineering personnel shall demonstrate a working level knowledge of the civil/structural engineering-related sections and/or requirements of the following related Department of Energy (DOE) Orders:

- DOE Order 5480.28, Natural Phenomena Hazards Mitigation
- DOE Order 6430.1A, General Design Criteria, Section B, Uniform Building Code (UBC)

a. Describe the purpose, scope, and application of the requirements detailed in the above Orders.

DOE Order 5480.28, Natural Phenomena Hazards Mitigation.

DOE O 420.1, Facility Safety, superseded DOE Order 5480.28. The information provided below is with respect to DOE O 420.1.

The objective of this Order is to establish facility safety requirements related to: nuclear safety design, criticality safety, fire protection and natural phenomena hazards mitigation.

Essentially, this order is applicable to DOE-owned or leased nuclear and non-nuclear facilities. The requirements vary depending on the facility classification. DOE Order 420.1 and the associated Implementation Guides establish a graded approach in which NPH requirements are provided for various performance categories, each with a specified performance goal. The graded approach enables design or evaluation of DOE structures, systems, and components to be performed in a manner consistent with their importance to safety, importance to mission, and cost. The graded approach enables cost-benefit studies and establishment of priorities for existing facilities. Probabilistic performance goals enable the development of consistent criteria both for all natural phenomena hazards and for all DOE facilities which are located throughout the United States.

Five performance categories are specified for the design/evaluation of DOE SSC's for NPH ranging from 0 through 4 as follows:

0 No safety, mission, or cost considerations;
1 Maintain Occupant Safety;
2 Occupant safety, continued operation with minimum interruption;
3 Occupant safety, continued operation, hazard confinement; and
4 Occupant safety, continued operation, confidence of hazard confinement SSCs are to be placed in categories in accordance with DOE-STD-1021-93.

Quantitative performance goal probability values are applicable to each NPH (earthquake, wind, and flood) individually. DOE-STD-1020-94 provides earthquake and flood design and evaluation criteria for the DOE.

Activities that are regulated by other authorities (Nuclear Regulatory Commission, Navy Nuclear Propulsion Program, Nuclear Explosives and Weapons Safety Program, Department of Transportation, accelerator and fusion facilities) are excluded from these requirements.

This order is broken up into two sections. The first section identifies requirements applicable to DOE elements and the second section identifies the contractor requirements.

DOE Order 6430.1A, General Design Criteria, Section B, Uniform Building Code (UBC).

The purpose is to provide General Design Criteria (GDC) for use in the acquisition of the Department’s facilities and to establish responsibilities and authorities for the development and maintenance of these criteria.

The provisions of GDC apply to all Departmental Elements except as otherwise provided by statute or by specific delegation of authority from the Secretary of Energy, and all contractors and subcontractors performing work for the Department whose contract may involve planning, design, or facility acquisitions. This includes DOE-owned, -leased, or -controlled sites where Federal funds are used totally or in part, except where otherwise authorized by separate statute or where specific exemptions are granted by the Secretary or his designee.

The GDC is applicable to all facilities which are to be reported in the Department's Real Property Inventory System (RPIS), or in the General Services Administration's annual "Summary Report of Real Owned by the United States Throughout the World." The GDC is not intended to provide complete coverage for the diverse facilities in the DOE Complex. Specific project criteria and/or specifications need to be developed to satisfy the needs for a particular facility, incorporating applicable requirements of these general design criteria and supplemented with required criteria from applicable codes and standards. There is no intent that the GDC take precedence over other criteria, where those criteria meet or exceed the GDC requirements. Where there exists a conflict between those criteria and the GDC provided by this Order, however, the GDC governs

b. Discuss the graded approach process by which Department line management determines an appropriate level of coverage by civil/structural engineers. Include in this discussion factors that may influence the level of coverage.

The graded approach process is one in which Structures, Systems and Components (SSCs) are placed into performance categories such that the required level of analysis, documentation, and actions are commensurate with:

- The relative importance to safety, safeguards, the environment, and security;
- The expected magnitude of any hazard involved;
- The programmatic mission of a facility;

- The particular characteristic of the SSCs; and
- The cost and replaceability of the SSCs.

c. ***Discuss what constitutes acceptable contractor work performance consistent with the requirements of the above Orders.***

Contractor performance is considered acceptable if applicable Executive Orders, Federal laws, and regulations are satisfied. Best industry practices are used as a basis, as well as a graded approach to ensure that value and cost are balanced with the risks.

There are several areas that should be looked at to ensure compliance with civil/structural engineering-related requirements. A brief description of the items that should be looked at is provided below.

Nuclear Safety

- Siting factors, such as proximity to nearby facilities, for example airports, pipelines, and barge traffic;
- Defense in depth from radiological hazards, including physical barriers as well as administrative controls;
- The design facilitates deactivation, decommissioning and decontamination at end of life;
- The facility can be maintained in a safe state during inspections, testing, maintenance, repair and replacement of equipment while keeping in line with the ALARA; and
- Facility process systems shall be designed to minimize waste and mixing of radioactive and non-radioactive wastes.

Explosives Safety

- Facility structural design and construction shall comply with the requirements of TM5-1300, Structures to Resist the Effects of Accidental Explosions, and DOE/TIC-11268, A Manual for the Prediction of Blast and Fragment Loading of Structures.

Fire Protection

- A reliable water supply of adequate capacity for fire suppression;
- Noncombustible or fire-resistive construction is used commensurate with the fire hazard;
- Automatic fire extinguishing systems used when possible and in areas with SSCs, significant life safety hazards, and program interruption is unacceptable;
- Redundant fire protection systems used in areas where SSCs are vulnerable to fire damage and not redundant safety capability exists outside the fire area;

- A means to summon the fire department and to notify and evacuate personnel exists.
- Physical access and appropriate equipment to aid the fire department exists;
- A means to prevent the accidental release of significant quantities of contaminated products of combustion and fire fighting water to the environment exists;
- Fire hazards unique to the facility identified by the fire hazard analysis are addressed; and
- Fire protection systems shall be designed such that their inadvertent operation, inactivation or failure of structural stability will not result in the loss of vital safety functions or inoperability of safety class systems.

Nuclear Criticality Safety

The following ANSI/ANS standards identify requirements that must be followed. Some of these standards may not be applicable from a civil/structural standpoint:

- ANSI/ANS-8.1-1983,R88, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," however paragraphs 4.2.2 and 4.2.3, and paragraph 3.3 shall be followed as modified in section 4.3.3.d of this Order;
- ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," however paragraphs 4.1.2, 4.2.1 and 4.2.2 shall be followed as modified in section 4.3.3.c and e of this Order;
- ANSI/ANS-8.5-1986, "Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material";
- ANSI/ANS-8.6-1983,R88, "Safety in Conducting Subcritical Neutron-Multiplication Measurements in Situ," however paragraph 5.3 shall be followed as modified in section 4.3.3.f of this Order;
- ANSI/ANS-8.7-1975,R87, "Guide for Nuclear Criticality Safety in the Storage of Fissile Materials," however paragraph 5.2 shall be followed as modified by section 4.3.3.c of this Order;
- ANSI/ANS-8.9-1987, "Nuclear Criticality Safety Criteria for Steel-Pipe Intersections Containing Aqueous Solutions of Fissile Materials";
- ANSI/ANS-8.10-1983,R88, "Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement";
- ANSI/ANS-8.12-1987,R93, "Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors";
- ANSI/ANS-8.15-1981,R87, "Nuclear Criticality Control of Special Actinide Elements";
- ANSI/ANS-8.17-1984,R89, "Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors," however paragraph 4.3 shall be followed as modified in section 4.3.3.g of this Order;
- ANSI/ANS-8.19-1984,R89, "Administrative Practices for Nuclear Criticality Safety"; and
- ANSI/ANS-8.21-1995, "Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors".

Natural Phenomena

- Natural Phenomena Hazards (NPH) such as seismic, wind, flood, and lightning shall be considered with the building civil/structural features. One of the three Model Building Codes shall be followed if no other guidance is provided.

- Safety measures and design features used to mitigate the effects of floods are:

  ◊ Siting of the SSC above the design basis flood;
  ◊ Dikes and levees to keep elevated waters away for the facility;
  ◊ Development of emergency implementation plans and early warning systems;
  ◊ Design of sites with adequate drainage for abnormal levels of precipitation;
  ◊ Design of secondary drainage systems to preclude problems from pluggage of primary drainage systems (roofs and local areas of sites); and
  ◊ Sealing and hardening of SSC to prevent water damage.

- Safety measures and design features used to mitigate the effects of sustained winds are:

  ◊ Strengthening of surfaces of facilities to account for lateral and vertical wind loading;
  ◊ Design of facilities for internal pressures generated by extreme winds;
  ◊ Facility cladding and roofing to mitigate surface damage;
  ◊ Design for wind-driven missile damage; and
  ◊ Emergency plans and early warning systems to warn of and prepare for severe storms.

- Safety measures and design features used to mitigate the effects of tornadoes are:

  ◊ Strengthening of surfaces of facilities to account for lateral and vertical wind loading, and APC conditions;
  ◊ Design of facilities for internal pressures generated by extreme winds;
  ◊ Facility cladding and roofing to mitigate surface damage;
  ◊ Design for wind-driven missile damage; and
  ◊ Emergency plans and early warning systems to warn of and prepare for severe storms.

- Safety measures and design features used to mitigate the effects of earthquakes are:

  ◊ Siting of facilities in areas of low seismic activity
  ◊ Modeling, designing and modifying facilities to withstand appropriate seismic loads

- ◊ Developing safety analyses and adherence to operational requirements to assure that facilities operate within an adequate safety envelope
- ◊ Equipment qualifications, installation, internal design, and quality control to assure component performance

DOE Order 6430.1A, General Design Criteria, Section B, Uniform Building Code (UBC)

Section 0111 identifies the structural requirements. Some of the items that should be included when evaluating compliance are:

- All floor, roof, and wall framing members and slabs;
- All piers, walls, columns, footings, piles, and similar elements of the substructure;
- All other substructure and superstructure elements that are proportioned on the basis of stress, strength, and deflection requirements;
- Clear space and span requirements;
- Serviceability requirements;
- Applicable fire protection classification;
- Security requirements;
- Foundation conditions;
- Future expansion requirements;
- Architectural treatment;
- Climatic conditions; and
- Structural design loads for the specific facility and location.

Section Two identifies civil engineering requirements and factors that should be considered. The topical areas that should be considered are:

- Facility Siting;
- Subsurface Investigations;
- Surveying;
- Utilities Within Easements or Corridors;
- Demolition, Decontamination, and Decommissioning;
- Site Preparations;
- Dewatering;
- Shoring and Underpinning;
- Earthwork;
- Building Foundations;
- Railroad Design;
- Paving and Surfacing;
- Airports and Heliports;
- Piped Utility Materials;
- Corrosion Control;
- Water Distribution Systems;
- Sanitary Wastewater Collection and Stormwater Management Systems;
- Water Pollution Controls;

- Industrial Wastewater Treatment;
- Construction in Floodplains or on Wetlands;
- Power and Lighting;
- Exterior Communications and Alarm Systems;
- Site Improvements;
- Vehicular and Pedestrian Circulation;
- Physical Protection;
- Solid Waste Systems;
- Landscaping;
- Irrigation Systems; and
- Erosion control.

Numerous Orders, including DOE Order 6430.1A, General Design Criteria, have been superseded by DOE Order 430.1 on 8-25-95 and shall be implemented on a site-by-site basis through the establishment, by contract or financial assistance agreements, of site-specific performance criteria and a performance measurement system. However, the Orders superseded by DOE Order 430.1A, remain in effect until such incorporation takes place. Additionally, for specific facilities under the purview of the Defense Nuclear Facilities Safety Bouard, DOE Order 4330.4B, Maintenance Management Program, and DOE Order 6430.1A, General Design Criteria, remain in effect until 10 CFR 830.340, Maintenance Management, and DOE Order 420, Facility Safety, for defense nuclear facilities are issued finals.

2.2 ***Civil/structural engineering personnel shall demonstrate the ability to determine the adequacy of local compliance with the civil/structural engineering-related sections and/or requirements of the following Department of Energy (DOE) Orders:***

- DOE Order 5480.28, Natural Phenomena Hazards Mitigation
- DOE Order 6430.1A, General Design Criteria, Section B, Uniform Building Code (UBC)

a. ***Using the above Orders, prepare an action plan which adequately outlines interviews and observations to be conducted, and details documents to review during an evaluation of contractor compliance with the requirements of these Orders.***

Plan of Action

The following process of evaluating compliance with the DOE orders is a standard performance based process and is a recommended method to be followed, however, this process may be modified to fit the assessment objectives.

1. Determine the objectives or areas to be evaluated.
2. Based on a graded approach, determine the criteria (requirements) or level of acceptability that meets the objectives.
3. Become familiar with the source documents for the criteria.
4. Perform a document review.
5. Observe activities for the criteria.
6. Conduct interviews.

The order in which steps 4, 5, and 6 above are performed is not as important as the fact that they are all performed to complete satisfaction in meeting the objective. The information provide emphasizes a process approach as well as a requirements approach. The objective of this methodology is to ensure that the root cause of the problems are corrected rather than the symptomatic requirement non-compliance. More detailed information on how to perform interviews, observations, and document reviews are provided in section b below.

Below, are documents, observations and interviewees that are recommended to ensure civil/structural compliance with the DOE Orders and other referenced source documents. The specific topics to verify compliance against are detailed in part c of this question.

Note: The term building inspector as used below is defined to mean an individual who has the responsibility of ensuring the requirements of the Orders above are met. It may not necessarily mean an individual who is a Building Inspector Official.

Document Review

Many of the documents listed below deal with the programmatic administrative control of compliance to the orders above. A programmatic or administrative breakdown in these controls will lead to non-compliance of the orders. Only the civil/structural aspects of the documents should be reviewed.

- SAR;
- Facility program and operations procedures and policy manuals;
- Occurrence Reports;
- Lessons learned and Operating Experience weekly reports;
- Maintenance requests and work packages;
- Temporary modification control records;
- Equipment and system operating procedures;
- Natural phenomena hazards assessments;
- Fire hazards analysis;
- Meteorology historical data;
- Hydrology data;
- Seismic historical data;
- Design calculations;
- Building inspection reports;
- Soil erosion control and drainage plans;
- Survey reports;
- Soil reports; and
- Building plans and modifications (including vendor drawings).

Interviewees

- Building facility manager
- Building structural engineer
- Building civil engineer
- Building maintenance manager
- Building inspectors
- Maintenance workers

Questions

Besides the documents above, DOE Orders, and other source documents, a search on the Internet is recommended. The DOE-EH Technical Information Services Home Page has a significant amount of reference sources as well as lessons learned. There are other websites that may provide insight to problems that have occurred or present aspects that have not been thought of, but would be applicable to this compliance review.

Describe the process of design criteria determination for new facilities as well as modifications to existing facilities.

- This process should include a reference to the Safety Analysis Report (SAR). The basis for some of the items that are identified in DOE 420.1 and DOE Order 6430.1A will be found here;
- The applicable model building code should also be used as a source document;
- Landscaping and other terrain modifications should also be addressed;
- Reference to the graded approach should be mentioned; and
- Designs to facilitate decontamination and decommissioning in accordance with DOE Order 6430.1A section 1300-11 and DOE Order 5820.2A chapter V should also be addressed.

Describe the process when a possible non-compliance to the design criteria is found.

- See section 2.2 (d) for process.
- For nuclear facilities, this should include a reference to the Unreviewed Safety Question process identified in DOE Order 5480.21 to determine whether that process is applicable. The authorization basis may or may not be affected by changes or modifications in procedures or equipment.

How often are building inspections performed with respect to structural integrity? Include what items are looked at and how the inspection is performed.

- Some of the topics do not need to be inspected as often as others. One of the most important items that should be emphasized is that the physical inspections should be very detailed to ensure that conditions have not changed. In many cases, the physical changes are not noticed right away due to gradual changes. For example, cracks in the concrete floors, or walls over a period of time may be an indication of ground shifting due to changes in hydrology conditions due to landscaping, corrosion of strengthening material in the concrete, or just settlement of the foundation. As another example, what may seem like a minor corrosion problem on the outside of the material may only be a superficial indication of significant corrosion degradation of the material on the inside; and
- The inspection should also include the surrounding area outside the building to ensure any civil engineering aspects do not affect the building.

What is the method of prioritizing maintenance work to be performed? What happens when no funds are available to perform the work?

- Documentation identifying the process and rational should be provided. A cost-benefit (hazard) analysis process should be evident.

<u>Observations</u>

Observe a building inspector perform an inspection. This should include the surrounding area outside the building.

This observation has two purposes:

1) Evaluate the building inspector's adequacy in performing a thorough inspection.
2) Perform a walkdown of the area to ensure compliance with the requirements.

Observe a structural or civil related building maintenance project.

- The drawings, work package, and code requirements should also be reviewed; and
- If outside vendors are performing the work, a review of the process that is being used to ensure compliance with the DOE and site specific requirements should be performed. Even though the requirements may be written into the contract, a process for verification of compliance, at least on a spot check basis, should be evident.

b. ***Using an appropriate level of coverage, conduct an evaluation of contractor compliance with the requirements of the Orders. During this evaluation, demonstrate the ability to properly conduct interviews, observations, and document reviews.***

The following guidance information is provided out of DOE-EM-STD-5505-96, Operations Assessments. Even though the information is oriented towards an operational assessment, the concept is still the same for an evaluation of contractor compliance to requirements of Orders. One area that may be slightly different is the amount of emphasis on document review. For structural/civil engineering compliance, document review has a larger emphasis than a normal Operational Assessment.

Interviews

The interview process will be an important information-gathering tool. Interviews are an effective method of determining level of knowledge and familiarity with activity policies and procedures. An interview can be the key step in following up on leads. To ensure that all relevant information is obtained efficiently and accurately, each interview should be planned and organized.

How to Prepare for Interviews Planning is critical to the success of any interview. It enables the assessor to maximize the use of interview time. The planning process does not have to be formal; it may be simply a matter of determining what information is being sought. The assessor should determine which interviews can be conducted during walkthroughs, special activities, routine operations at the activity, and which interviews require coordination and scheduling with activity management. In planning the interview, the assessor should identify the goals for the interview and the items to be discussed so that a logical sequence of questions can be developed beforehand. It may also be appropriate to bring relevant reference documentation for review during interviews.

Conducting Interviews Two types of questions are routinely used during the interview process: open-ended and closed-ended. A good mix of these two types of questions should provide the assessor with enough information. An open-ended question places the burden of conversation on the interviewee and gives the assessor time to analyze what the interviewee is saying. It reduces the total number of questions asked. An open-ended question elicits more than a yes or no response and is very useful when starting a line of questioning in a new subject area. For example, asking an operator to "explain" or "describe" an event is an open-ended question. The advantage of open-ended questions is that they usually provide a large amount of information about the topic of interest to the assessor. The interviewee does most of the talking in responding to them, and the information provided is generally volunteered. A closed-ended question is a specific question that is often answered with only one or two words. Examples are "what," "when," "who," and "where" questions. Closed-ended questions place the burden of conversation on the assessor in that the assessor spends much more time thinking of and stating the question than it takes the interviewee to answer it. The advantages of closed-ended questions are that they allow the interviewer to obtain specific information about a topic of interest, are less time-consuming to answer, and are easier to record. Assessors should avoid using only closed-ended questions as they can elicit insufficient information, and require a lot of follow-up. The proper combination of open-ended and closed-ended questions will provide the most efficient use of time for both the assessor and the activity. To prevent the interviewee from digressing from the topic of interest, the assessor must direct the interview. The assessor’s use of leading questions should be minimized. In a leading question, the assessor gives the interviewee a partial answer and expects the interviewee to complete it, or the assessor gives the complete answer and expects the interviewee to agree or disagree with it.

During the interview, the interviewer should continuously evaluate the information being gathered, and ask follow up questions when necessary. This may lead to additional paths of discussion that are necessary to clarify the topic. Before concluding the interview, the assessor should attempt to summarize the information received from the interviewee. This will ensure that the assessor has correctly interpreted and recorded the information provided during the interview. After completion of an interview, the assessor should decipher, analyze, and evaluate the notes taken and identify areas that require follow up. The assessor should decide whether follow-up observations, document reviews, or interviews are required to clarify the information gathered during the interview. An important point to remember is that the information gathered during an interview, observation, or document review should be corroborated with other information. In order to validate apparent deviations from requirements and identify programmatic breakdowns or widespread problems, more than one assessment technique should normally be used.

Where and When to Conduct Interviews. During an operations assessment, most interviews should be conducted while performing observations and document reviews. If necessary, interviews can also be scheduled and conducted separately. For example, operators and shift supervisors can be interviewed during rounds and while conducting operations, as time permits. However, the assessor must ensure that the operators are not distracted from performing their duties while being interviewed during operational activities. If it is necessary, these personnel can also be interviewed in a more formal setting such as an office or conference room. In general, operators and shift supervisors can be interviewed at their work location. Conversely, it is usually best to interview activity managers, operations supervisors, and staff personnel in their offices or in another convenient location. Assessors should coordinate with the interviewee to establish the time and location of scheduled interviews. To minimize the impact on activity operations, assessors should always plan to arrive at the interview location on time, or reschedule the interview.

Observations

Observation is usually the most effective technique used during an operations assessment. Observing activities as they are performed provides information directly related to the effectiveness of operations. Observations should be combined with interviews and document reviews to paint an accurate picture of activity operations.

How to Observe In preparing for and performing observations, there are several things to keep in mind:

- Be familiar with the operations;
- Be familiar with the guidelines and use them as an expectation baseline;
- Pay close attention to ensure every detail of the observation is taken in and recorded;
- Follow your intuition. If something does not look or seem right, check further. Assume your intuition is correct until your research proves otherwise;
- Take copious notes. This will make it easier to follow up on your observations; and
- Data gathered from observations should be verified and cross-checked by the following methods: observe the same operation being performed by different personnel, observe different operations on the same shift, or observe different shifts performing similar operations.

These principles can be applied to all observations conducted during an assessment. For example, while observing maintenance on a contaminated valve at a waste-water processing facility, the assessor may review the work documentation and applicable facility operating and radiological control procedures before the observation. This will allow the assessor to become familiar with the guidelines to be used as an expectation baseline for the observation. While observing the operation, the assessor should watch the performance of as many operations personnel as possible and take notes on what is observed. Finally, the assessor should review these notes to identify any apparent deviations from requirements and determine the follow up actions necessary to validate or disprove them.

Where and When to Observe Observations can be conducted the entire time that the assessor is at an activity. Observations can take place during scheduled activities (drills, maintenance operations, system alignments, etc.) or can be conducted during activity walkthroughs and tours. The activity plan of the day or plan of the week should aid in identifying the time and place for observing scheduled activities.

Document Review

The assessment team should review applicable documents both prior to and during the assessment. In general, document reviews are conducted for the following reasons:

- To gain familiarity with the requirements contained in activity policies, procedures, etc.;
- To validate or disprove apparent deviations from requirements and identify programmatic breakdowns or widespread problems;
- To investigate apparent inconsistencies between activity policies and procedures, and DOE Directives; and
- To refresh the assessors knowledge of the elements of conduct of operations. Applicable DOE standards and guidelines should be reviewed prior to the assessment. There are DOE Standards for each element of conduct of operations.

Since operations assessments should be focused on operations, assessors should not spend the majority of their time conducting document reviews. Document reviews should be used by assessors to establish their expectations concerning activity operations and when pursuing leads developed from observations and interviews

Reviewing Documents. In general, an assessor should keep the following guidance in mind when conducting document reviews:

- Identify questions for interviews and key steps or sections of operating procedures to observe;
- Identify administrative and technical source documents and higher-level procedures to check; and
- Take specific and accurate notes to allow efficient follow up, if necessary.

Documents can be reviewed before, during, or after observations and interviews. To start an assessment of chemistry and unique processes, for example, the assessor could decide to review operating documents such as activity logs and cross-check them for consistency with each other and the governing procedure. For instance, if a sample was taken, analyzed, and reported, do the sample logs and the discharge logs agree? Was the sample taken, analyzed, and the results reported prior to the discharge occurring? Is this required? If discrepancies are found, additional observations, interviews, and document reviews should be conducted. The assessor could also start the assessment of this area by reviewing activity and site procedures. Once these procedures are reviewed, an observation of the sampling process could be conducted to determine if deviations from requirements exist.

When and Where to Review Documents. Document reviews can be conducted in conjunction with observations and interviews, as well as separately.

As stated above, documents can also be reviewed as a separate activity. Complicated documents such as program procedures and policy manuals may require dedicated, in-depth review by assessors. These reviews can be done at the activity (in a meeting room, for example), or at the assessment team's operating base.

Pursuing leads. One of the most important aspects in verifying compliance is “pursuing a lead.” This term has many phrases such as “closing the loop” or “pulling the string.” Regardless of what it is called, the objective is the same. "Pursuing leads" is the process of following up on an apparent deviation from requirements using observations, interviews, and document reviews. A lead is considered a deviation from expectations or an apparent deviation from requirements that is developed as a result of observations, interviews, or document reviews. The process of pursuing leads should continue until all leads have been validated, and any programmatic breakdowns or widespread problems are identified, or until sufficient evidence exists to disprove the apparent discrepancy. The ability to identify leads and pursue leads depends on the intuition, experience, and tenacity of the assessor. To effectively identify leads, an assessor must:

- Trust intuition. If something does not seem right, keep looking until verified right or wrong;
- Do not assume more than evidence supports;
- Maintain a questioning attitude about all that is observed during the assessment; and
- Be familiar with the requirements of each area of conduct of operations and activity policies and procedures.

Furthermore, to pursue leads effectively, an assessor must:

- Seek supporting information and evidence through follow up observations, interviews, and document reviews;
- Investigate the programmatic aspects (Is there a programmatic breakdown or widespread problem, or is this an isolated case?);
- Be tenacious and persistent until satisfied with the answers obtained; and
- Use good judgment when determining how much time is to be spent on one issue (If pursuit of a lead will result in time constraints on the assessment, discuss the issue with the team leader.)

Pursuing leads is a vital part of the operations assessment process. It is not sufficient to just identify apparent deviations from requirements. In order to develop well-supported findings and concerns, the assessment team must confirm all findings and develop concerns that direct activity management's attention to the underlying causes. To illustrate the process of pursuing leads, consider an operator pumping a wastewater retention basin to the environment through a permitted outfall via a natural creek flowing next to the site boundary. During the assessment, an assessor notes that one operator bypasses the pH meter when starting the discharge to the creek. This action is not stated in the procedure. This is a deviation from the expectation that operators should follow a procedure and should not take important action which is not covered in a procedure. The assessor needs to determine why the operator took an action which was not covered in the procedure. Bypassing alarms, warning devices and instrumentation is a serious operational matter. For instance, the assessor could decide to interview the operator during the basin pumping operation. During the interview, the operator states that she always bypasses the pH meter on starting the pump because the shift supervisor has instructed her to do so. Now the situation has changed in that it is not necessarily one operator who is not following procedures; it is the shift supervisor disregarding written procedures and instructing the shift operators accordingly. So far, the assessor has been limited to observing only one shift. Therefore, an observation of an operator on a different shift might be appropriate. During this observation, the assessor notes that the second operator also bypasses the pH meter in the same way. When questioned, the operator states that the shift supervisor provided the same instruction since it reduces the alarms that are received in the control room. The assessor now can conclude that this practice which is not allowed by procedure is not limited to one operator or shift.

There are several directions in which the assessor could proceed. For example, the assessor could interview personnel from the engineering or maintenance or training organization. The questioning may indicate that supervisors and operators are living with system deficiencies because of a design or maintenance problem with the pH circuit or defective cell system. The logical questions that the assessor should ask are: Have the problem alarms been identified? Has engineering evaluated the problems? Is operations compensating for poor design or performance? How was the determination made that the alarms received are false? What was the basis and who authorized bypassing an NPDES instrument? Is bypassing the cell approved? Why are there no compensatory measures in the procedure to ensure that the cell is not bypassed during the discharge?

There are some areas of concern that may arise from this scenario. The fundamental issue of concern related to conduct of operations is the bypassing of a safety or monitoring system.

Another area of potential concern is that there may be a reportable issue to the state or federal environmental protection agency because the monitoring system is part of the site environmental permit. An additional area of concern might be why is there a bypass at all. More generally, why do trained personnel, who should be knowledgeable about alarms, permits, bypassing systems, instrumentation, procedural protocol, not challenge the verbal direction to bypass systems without extraordinary compensatory measures.

Other areas that the assessor might investigate to pursue leads further include:

- Determining if the procedure change system is too cumbersome for operators to use for known problems;

- Investigating to see if the technical engineering group submit procedure changes in response to design problems;
- Analyzing if the procedure writer's group has been tasked with higher priority projects than making changes to the retention basin procedure; and
- Exploring activity management involvement in assuring that procedures are followed according to management expectation and that they remain current.

c. ***Given data from an evaluation, analyze the results of the evaluation to determine contractor compliance or noncompliance with the requirements.***

DOE Order 5480.28, Natural Phenomena Hazards Mitigation

DOE Order 420.1, Facility Safety, superseded DOE Order 5480.28. The information provided below is with respect to DOE Order 420.1.

There are several areas that should be looked at to ensure compliance with civil/structural engineering-related requirements. A brief description of the items that should be looked at is provided below.

Nuclear Safety

- Siting factors, such as proximity to nearby facilities, for example airports, pipelines, and barge traffic;
- Defense in depth from radiological hazards, including physical barriers as well as administrative controls;
- The design facilitates deactivation, decommissioning and decontamination at end of life;
- The facility can be maintained in a safe state during inspections, testing, maintenance, repair and replacement of equipment while keeping in line with the ALARA; and
- Facility process systems shall be designed to minimize wastes and mixing of radioactive and non-radioactive wastes.

Explosives Safety

- Facility structural design and construction shall comply with the requirements of TM5-1300, Structures to Resist the Effects of Accidental Explosions, and DOE/TIC-11268, A Manual for the Prediction of Blast and Fragment Loading of Structures.

Fire Protection

- A reliable water supply of adequate capacity for fire suppression;
- Noncombustible or fire-resistive construction is used commensurate with the fire hazard;
- Automatic fire extinguishing systems used when possible and in areas with SSCs, significant life safety hazards, and program interruption is unacceptable;
- Redundant fire protection systems used in areas where SSCs are vulnerable to fire damage and not redundant safety capability exists outside the fire area;
- A means to summon the fire department and to notify and evacuate personnel exists.
- Physical access and appropriate equipment to aid the fire department exists;

- A means to prevent the accidental release of significant quantities of contaminated products of combustion and fire fighting water to the environment exists;
- Fire hazards unique to the facility identified by the fire hazard analysis are addressed; and
- Fire protection systems shall be designed such that their inadvertent operation, inactivation or failure of structural stability will not result in the loss of vital safety functions or inoperability of safety class systems.

Nuclear Criticality Safety

The following ANSI/ANS standards identify requirements that must be followed. Some of these standards may not be applicable from a civil/structural standpoint:

- ANSI/ANS-8.1-1983,R88, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," however paragraphs 4.2.2 and 4.2.3, and paragraph 3.3 shall be followed as modified in section 4.3.3.d of this Order;
- ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," however paragraphs 4.1.2, 4.2.1 and 4.2.2 shall be followed as modified in section 4.3.3.c and e of this Order;
- ANSI/ANS-8.5-1986, "Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material";
- ANSI/ANS-8.6-1983,R88, "Safety in Conducting Subcritical Neutron-Multiplication Measurements in Situ," however paragraph 5.3 shall be followed as modified in section 4.3.3.f of this Order;
- ANSI/ANS-8.7-1975,R87, "Guide for Nuclear Criticality Safety in the Storage of Fissile Materials," however paragraph 5.2 shall be followed as modified by section 4.3.3.c of this Order;
- ANSI/ANS-8.9-1987, "Nuclear Criticality Safety Criteria for Steel-Pipe Intersections Containing Aqueous Solutions of Fissile Materials";
- ANSI/ANS-8.10-1983,R88, "Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement";
- ANSI/ANS-8.12-1987,R93, "Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors";
- ANSI/ANS-8.15-1981,R87, "Nuclear Criticality Control of Special Actinide Elements";
- ANSI/ANS-8.17-1984,R89, "Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors," however paragraph 4.3 shall be followed as modified in section 4.3.3.g of this Order;
- ANSI/ANS-8.19-1984,R89, "Administrative Practices for Nuclear Criticality Safety"; and
- ANSI/ANS-8.21-1995, "Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors".

Natural Phenomena

- Natural Phenomena Hazards (NPH) such as seismic, wind, flood, and lightning shall be considered with the building civil/structural features. One of the three Model Building Codes shall be followed if no other guidance is provided.

- Safety measures and design features used to mitigate the effects of floods are:

  ◊ Siting of the SSC above the design basis flood;
  ◊ Dikes and levees to keep elevated waters away for the facility;
  ◊ Development of emergency implementation plans and early warning systems;
  ◊ Design of sites with adequate drainage for abnormal levels of precipitation;
  ◊ Design of secondary drainage systems to preclude problems from plugage of primary drainage systems (roofs and local areas of sites); and
  ◊ Sealing and hardening of SSC to prevent water damage.

- Safety measures and design features used to mitigate the effects of sustained winds are:

  ◊ Strengthening of surfaces of facilities to account for lateral and vertical wind loading;
  ◊ Design of facilities for internal pressures generated by extreme winds;
  ◊ Facility cladding and roofing to mitigate surface damage;
  ◊ Design for wind-driven missile damage; and
  ◊ Emergency plans and early warning systems to warn of and prepare for severe storms.

- Safety measures and design features used to mitigate the effects of tornadoes are:

  ◊ Strengthening of surfaces of facilities to account for lateral and vertical wind loading, and APC conditions;
  ◊ Design of facilities for internal pressures generated by extreme winds;
  ◊ Facility cladding and roofing to mitigate surface damage;
  ◊ Design for wind-driven missile damage; and
  ◊ Emergency plans and early warning systems to warn of and prepare for severe storms.

- Safety measures and design features used to mitigate the effects of earthquakes are:

  ◊ Siting of facilities in areas of low seismic activity
  ◊ Modeling, designing and modifying facilities to withstand appropriate seismic loads
  ◊ Developing safety analyses and adherence to operational requirements to assure that facilities operate within an adequate safety envelope

◊ Equipment qualifications, installation, internal design, and quality control to assure component performance

DOE Order 6430.1A, General Design Criteria, Section B, Uniform Building Code (UBC)

Section 0111 identifies the structural requirements. Some of the items that should be included when evaluating compliance are:

- All floor, roof, and wall framing members and slabs;
- All piers, walls, columns, footings, piles, and similar elements of the substructure;
- All other substructure and superstructure elements that are proportioned on the basis of stress, strength, and deflection requirements;
- Clear space and span requirements;
- Serviceability requirements;
- Applicable fire protection classification;
- Security requirements;
- Foundation conditions;
- Future expansion requirements;
- Architectural treatment;
- Climatic conditions; and
- Structural design loads for the specific facility and location.

Section Two identifies civil engineering requirements and factors that should be considered. The topical areas that should be considered are:

- Facility Siting;
- Subsurface Investigations;
- Surveying;
- Utilities Within Easements or Corridors;
- Demolition, Decontamination, and Decommissioning;
- Site Preparations;
- Dewatering;
- Shoring and Underpinning;
- Earthwork;
- Building Foundations;
- Railroad Design;
- Paving and Surfacing;
- Airports and Heliports;
- Piped Utility Materials;
- Corrosion Control;
- Water Distribution Systems;
- Sanitary Wastewater Collection and Stormwater Management Systems;
- Water Pollution Controls;
- Industrial Wastewater Treatment;
- Construction in Floodplains or on Wetlands;

- Power and Lighting;
- Exterior Communications and Alarm Systems;
- Site Improvements;
- Vehicular and Pedestrian Circulation;
- Physical Protection;
- Solid Waste Systems;
- Landscaping;
- Irrigation Systems; and
- Erosion control.

d. Given the results from an analysis of contractor compliance or noncompliance, document the results and communicate them to contractor and Department line management.

The results of an evaluation should be communicated to the contractor and DOE line management as quickly as possible. The individual who performed the evaluation should submit the report through his/her management for review and concurrence then transmitted to the contractor. All non-compliance items should be validated. Part of the validation process of non-compliance should include a discussion with the contractor to clear up any misunderstandings. If a non-compliance was corrected it should still be reported, but as corrected to meet compliance during the evaluation period. The following important elements of a report should be in the report.

Introduction This section should identify the purpose and scope of the assessment.

Executive Summary This is not normally needed unless a large area evaluation was performed in which the report would be several pages long and it would provide upper management with an easy to read summary of the overall evaluation.

Objectives or areas covered This should also include the personnel interviewed (titles), observations, and documents reviewed.

Identification of non-compliance This should include the following:

- Statement of the non-compliance;
- Source document reference;
- Area of non-compliance or explanation if not definitely clear; and
- Explanation or definition of terms or levels of non-compliance if applicable.

Individual(s) performing the evaluation Should a question arise later, the person who performed the evaluation may need to be contacted.

Because this is a DOE evaluation, unless specifically desired or required, recommendations and prioritization of non-compliance should not be provided. The contractor typically has the right and is paid to make decisions as long as it is within the bounds of the contract, regulations and other requirements.

2.3 Civil/structural engineering personnel shall demonstrate a working level knowledge of the following civil/structural engineering-related Department of Energy (DOE) Technical Standards:

- DOE-STD-1020-94, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities
- DOE-STD-1021-93, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components
- DOE-STD-1022-94, Natural Phenomena Hazards Site-Characterization Criteria
- DOE-STD-1024-92, Guidelines for Use of Probabilistic Seismic Hazards Curves at DOE Sites

Supporting Knowledge and/or Skills

a. Describe the purpose, scope, and application of the requirements detailed in the listed technical standards.

DOE-STD-1020-94

Purpose: This DOE Standard gives design and evaluation criteria for Natural Phenomena Hazards (NPH) effects as guidance for implementing the NPH mitigation requirements of DOE Order 420.1 and the associated implementation guides. It is intended to provide consistent design and evaluation criteria for protection against natural phenomena hazards at DOE sites throughout the United States.

Scope: The design and evaluation criteria presented by this standard are meant to control the level of conservatism introduced into the design/evaluation process such that earthquake, wind, and flood hazards are treated on a consistent basis. These criteria also employ a graded approach to ensure that the level of conservatism and rigor in design/evaluation is appropriate for facility characteristics such as importance, hazards to people on and off site, and threat to the environment. For each natural phenomena covered, these criteria consist of the following:

- Performance categories and target performance goals as specified in the DOE Order 420.1 NPH Implementation Guide and DOE-STD-1021;
- Specified probability levels from which natural phenomena hazard loading on structures, equipment, and systems is developed; and,
- Design and evaluation procedures to evaluate response to NPH loads and criteria to assess whether or not computed response is permissible.

Application: These criteria apply to the design of new facilities and the evaluation of existing facilities. They may also be used for modification and upgrading of existing facilities as appropriate. The application of NPH design requirements to structures, systems and components (SSCs) shall be based on the life-safety or the safety classifications for the SSCs as established by safety analysis.

DOE-STD-1021-93

Purpose: This DOE Standard gives design and evaluation criteria for NPH for selecting performance categories (PCs) of SSCs in accordance with the requirements specified in DOE order 420.1 and the associated implementation guides. It also recommends procedures for consistent application of the determined PC criteria so that the DOE review and approval process is simplified.

Scope: The criteria and recommendations presented in this standard shall apply to performance categorization of SSCs for the purpose of mitigating natural hazards phenomena in all DOE facilities covered by DOE Order 420.1.

Application: The provisions of this standard apply only to NPH evaluation of SSCs. Application of basic categorization guidelines presented in this standard will establish the preliminary performance category of SSCs. The procedural steps presented are general recommendations for NPH performance categorization only, and are not intended to provide procedures for performing facility safety reviews or accident analyses.

DOE-STD-1022-94

Purpose: This DOE Standard provides criteria for site characterization to provide site-specific information for implementing the requirements of DOE order 420.1 and the associated implementation guides. Additionally the purpose of this standard is also to develop a sitewide database related to NPH that should be obtained to support individual safety analysis reports (SARs). Appropriate approaches are outlined to ensure that the current state-of-the-art methodology is being used in the site characterization.

Scope: The criteria and recommendations in this standard shall apply to site characterization for the purpose of mitigating NPH in all DOE facilities covered by DOE Order 420.1. Criteria for site characterization not related to NPH are generally not included in this document unless they are deemed necessary for clarification. General and detailed site characterization requirements are provided in the areas of meteorology, hydrology, geology, seismology and geotechnical studies.

Application: The criteria and recommendations in this standard shall apply to site characterization for the purpose of mitigating the effects of NPH in all DOE facilities covered by DOE Order 420.1.

DOE-STD-1024-92

Purpose: This standard provides an interim DOE position regarding how the Lawrence Livermore National Laboratory (LLNL) and the Electric Power Research Institute (EPRI) studies for development of seismic hazard curves should be used to assess seismic issues for existing and future facility seismic designs.

Scope: This standard will be operative for about 2 years. The DOE, in cooperation with NRC and EPRI has initiated a seismic hazard program which is expected to result in more stable seismic hazards estimates. An updated standard will be completed at that time.

Application: This standard explicitly applies to all DOE sites east of about 104W. The Rocky Flats site, the Paducah, Kentucky site and DOE facilities which are licensed by the Nuclear Regulatory Commission are excluded from the standard. Energy sites in the Western United States should be aware of the position, particularly when developing site-specific probabilistic hazard curves.

b. Discuss the graded approach process by which Department line management determines an appropriate level of coverage by civil/structural engineers. Include in this discussion factors that may influence the level of coverage.

DOE Order 420.1 and the associated Implementation Guides establish a graded approach in which NPH requirements are provided for various performance categories, each with a specified performance goal. The graded approach enables design or evaluation of DOE SSCs to be performed in a manner consistent with their importance to safety, importance to mission, and cost. The graded approach enables cost-benefit studies and establishment of priorities for existing facilities. Probabilistic performance goals enable the development of consistent criteria both for all natural phenomena hazards and for all DOE facilities which are located throughout the United States.

Five performance categories are specified for the design/evaluation of DOE SSCs for NPH ranging from 0 through 4 as follow:

(0) No safety, mission, or cost considerations;
(1) Maintain occupant safety;
(2) Occupant safety, continued operation with minimum interruption;
(3) Occupant safety, continued operation, hazard confinement; and,
(4) Occupant safety, continued operation, confidence of hazard confinement SSCs are to be placed in categories in accordance with DOE-STD-1021-93.

Quantitative performance goal probability values are applicable to each NPH (earthquake, wind, and flood) individually. DOE-STD-1020-94 provides earthquake and flood design and evaluation criteria for the DOE. Appropriate performance goals are set for each performance category SSC.

Coverage by Civil/Structural engineering resources may be effectively assigned utilizing the evaluation approach for an existing SSC as defined in DOE-STD-1020-94. That process includes the following elements:

- Collect design documents, conduct Site visit & operator interviews. Note differences between design & as-is condition. Determine performance categories for SSCs. Calculate as-is NPH capacity/demand by DOE-STD-1020;
- If criteria are met, the SSC is adequate for natural phenomena hazards;
- If criteria are not met, alternate options must be considered;
- Upgrade easy-to-remedy deficiencies or weaknesses;
- If upgrades are sufficient, SSC is adequate for NPH;
- If close to meeting criteria, reevaluate using hazard probability of twice the recommended value;
- If unsuccessful, conduct more rigorous evaluation removing added conservatism introduced by initial evaluation methods;
- If successful, SSC is adequate for NPH; and,
- If unsuccessful and a backfit analysis indicates more work is necessary, strengthen SSC sufficiently to meet DOE-STD-1020 OR change the usage of the SSC to a category with less stringent requirements.

c. Discuss what constitutes acceptable contractor work performance consistent with the requirements of the above orders.

Natural Phenomena Hazards Mitigation – The contractor is responsible to ensure that all DOE facilities are designed, constructed, and operated so that the general public, workers, and the environment are protected from the impact of Natural Phenomena Hazards (NPHs). The provisions of this requirement apply to DOE sites and facilities and they cover all natural phenomena hazards such as seismic, wind, flood, lightning. Where no specific requirements are specified, model building codes or national consensus industry standards shall be used.

General Requirements – For hazardous facilities, safety analyses shall include the ability of SSCs and personnel to perform their intended safety functions under the effects of natural phenomena.

Natural Phenomena Mitigation Design Requirements – SSCs shall be designed, constructed and operated to withstand the effects of natural phenomena as necessary to ensure the confinement of hazardous material, the operation of essential facilities, the protection of government property, and the protection of life safety for occupants of DOE buildings. The design process shall consider potential damage and failure of systems, structures and components due to both direct and indirect natural phenomena effects, including common cause effects and interactions from failures of other SSCs. Furthermore, the seismic requirements of Executive Order 12699 shall be addressed.

SSCs for new DOE facilities, and additions or major modifications to existing systems, structures and components shall be designed, constructed and operated to meet the requirements in the previous paragraph. Any additions and modifications to existing DOE facilities shall not degrade the performance of existing SSCs to the extent that the objectives in this Section cannot be achieved under the effects of natural phenomena.

Evaluation and Upgrade of Existing DOE Facilities – SSCs in existing DOE facilities shall be evaluated when there is a significant degradation in the safety basis for the facility. Furthermore, the seismic requirements of Executive Order 12941 shall be addressed.

If any of the conditions above are satisfied then the contractor/operator shall establish a plan for evaluating the affected SSCs. The plan shall incorporate a schedule for evaluation taking into account programmatic mission considerations and the safety significance of the potential failure of SSCs due to natural phenomena.

If the evaluation of existing SSCs identifies natural phenomena mitigation deficiencies, the contractor/operator shall establish an upgrade plan for the affected SSCs.

The upgrade plan shall incorporate a prioritized schedule for upgrading the SSCs. The upgrade plan shall address possible time or funding constraints as well as programmatic mission considerations.

Natural Phenomena Hazards Assessment – The design and evaluation of facilities to withstand natural phenomena shall be based on an assessment of the likelihood of future natural phenomena occurrences. The natural phenomena hazards assessment shall be conducted commensurate with a graded approach and commensurate with the potential hazard of the facility.

For new Sites, natural phenomena hazards assessment shall be conducted commensurate with a graded approach to the facility. Site planning shall consider the consequences of all types of natural phenomena hazards. For existing Sites, if there are significant changes in natural phenomena hazards assessment methodology or site-specific information, the natural phenomena hazards assessments shall be reviewed and shall be updated, as necessary. A review of the natural phenomena hazards assessment shall be conducted at least every 10 years. The review shall include recommendations to DOE on the need for updating the existing natural phenomena hazards assessments based on identification of any significant changes in methods or data.

Natural Phenomena Detection – Facilities or sites with hazardous materials shall have instrumentation or other means to detect and record the occurrence and severity of seismic events.

Post-Natural Phenomena Procedures – Facilities or sites with hazardous materials shall have procedures that include, inspecting the facility for damage caused by severe natural phenomena, and placing the facility into a safe configuration when such damage has occurred.

d. ***Discuss how hazard and accident analyses are used for structures, systems, and components.***

Hazard Analysis – Provides final facility hazard classification and considers and incorporates into programmatic requirements measures to protect workers, the public, and the environment from hazardous and accident conditions. Safety-significant structures, systems, and components that are major contributors to worker safety and defense in depth are identified in the hazard analysis. Hazard analysis considers the complete spectrum of accidents that may occur due to facility operations; analyzes potential accident consequences to the public and workers; estimates likelihood of occurrence; identifies and assesses associated preventive and mitigative features; identifies safety-significant SSCs; and identifies a selected subset of accidents, designated DBAs, to be formally defined in accident analysis.

Accident Analysis – Designates safety-class structures, systems, and components and safety controls (i.e., TSRs) as a function of Evaluation Guidelines. Accident analysis is a follow-on effort to the hazard analysis, not a fundamentally new examination requiring extensive original work. Accident analysis evaluates DBAs for comparison with Evaluation Guidelines to identify and assess the adequacy of safety-class SSCs.

e. ***Compare and contrast the following terms:***

- Safety class
- Safety significance
- Safety-related

Safety-class structures, systems, and components (safety-class SSCs) – SSCs including primary environmental monitors and portions of process systems, whose failure could adversely affect the environment, or safety and health of the public as identified by safety analyses. (DOE 5480.30) Safety-class SSCs are SSCs whose preventive or mitigative function is necessary to keep hazardous material exposure to the public below the offsite Evaluation Guidelines. This definition would typically exclude items such as primary environmental monitors and most process equipment.

Safety-significant structures, systems, and components (safety-significant SSCs) – SSCs not designated as safety-class SSCs but whose preventive or mitigative function is a major contributor to defense in depth (i.e., prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis.

As a general rule of thumb, safety-significant SSC designations based on worker safety are limited to those SSCs whose failure is estimated to result in an acute worker fatality or serious injuries to workers. Serious injuries, as used in this definition, refers to medical treatment for immediately life-threatening or permanently disabling injuries (e.g., loss of eye, loss of limb) from other than standard industrial hazards. It specifically excludes potential latent effects (e.g., potential carcinogenic effects of radiological exposure or uptake). Estimates of worker consequences for the purpose of safety-significant SSC designation are not intended to require detailed analytical modeling. Considerations should be based on engineering judgment of possible effects and the potential added value of safety-significant SSC designation.

Safety-related - The term safety-related is used in DOE safety Orders and Standards in two ways. First, the term is often used generally to discuss the overall system of safety control without specifically referring to a system's safety class, safety significance, programmatic safety posture, etc. In other cases, the term is used more specifically to refer to the programmatic infrastructure required to provide the defense-in-depth safety capability. The specific use is discussed below.

Structures, systems, or components that are major contributors to defense in depth are designated as safety-class or safety-significant SSCs. Additionally, DOE Standard 3009 provides guidance on grading the safety management programs (e.g., radiation protection, hazardous material protection, maintenance, procedures, training) that a facility must commit to in order to establish an adequate safety basis. The discipline imposed by safety management programs goes beyond merely supporting the assumptions identified in the hazard analysis and is an integral part of defense in depth.

By virtue of application of the graded approach, the majority of the engineered features in a facility will not be identified in the categories of safety-class or safety-significant SSCs even though they may perform some safety functions. However, such controls noted as a barrier or preventive or mitigative feature in the hazard and accident analyses must not be ignored in managing operations. Such a gross discrepancy would violate the safety basis documented in the SAR even if the controls are not designated safety-class or safety-significant, because programmatic commitments extend to these SSCs as well. For example, the commitment to a maintenance program means that the preventive and mitigative equipment noted as such in the SAR hazard analysis are included in the facility maintenance program. As a minimum, all aspects of defense in depth identified must be covered within the relevant safety management programs (e.g., maintenance, quality assurance) committed to in the SAR.

The screening criteria in DOE 5480.22 are considered a generally reasonable set of criteria to designate TSRs for defense in depth. These TSR controls may be captured in operational limits or in administrative controls, including those on safety management programs. This collection of TSRs formally acknowledges features that are of major significance to defense in depth.

Additionally, DOE Standard 3009 recognizes that the discipline imposed by programmatic commitments is at least as important to safety as the safety analysis itself. Programmatic commitments (e.g., radiation protection, maintenance, quality assurance) encompass a large number of details that are more appropriately covered in specific program documents (e.g., plans and procedures) external to the SAR. The cumulative effect of these details, however, are recognized as being important to facility safety, which is the rationale for a top level programmatic commitment becoming part of the safety basis.

2.4 Civil/structural engineering personnel shall demonstrate the ability to evaluate the adequacy of local compliance with the following civil/structural engineering-related Department of Energy (DOE) Technical Standards:

- DOE-STD-1020-94, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities
- DOE-STD-1021-93, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components
- DOE-STD-1022-94, Natural Phenomena Hazards Site-Characterization Criteria
- DOE-STD-1024-92, Guidelines for Use of Probabilistic Seismic Hazards Curves at DOE Sites

General

DOE will utilize a wide variety of assessment types and techniques to complete its assessment responsibilities. Individual or small group surveillance, inspection or walk-down activities will be appropriate in some cases. In other cases, a larger or more formal assessment team may be assembled. This decision is based on the significance, complexity and scope of the assessment. Each individual group within DOE must evaluate its unique circumstances and may establish detailed implementing procedures to cover its specific requirements and functions.

The following four substeps represent demonstration skills which are not covered under the scope of this study guide. However, discussion of assessment/evaluation techniques and methods are provided to assist the candidate in preparing to demonstrate the requisite skills. The material included here reflects current best practices as employed both within the Government and in the commercial sector.

a. Using two technical standards, prepare an action plan which adequately outlines interviews and observations to be conducted, and details documents to review during an evaluation of contractor compliance with the requirements of the selected technical standards.

<u>Define General Assessment Scope</u> – Define the general scope of the assessment, dependent on the selected technical standards. Appropriate DOE management shall ensure that the general assessment scope adequately meets specific needs and addresses all concerns. Scope refinement may be necessary later in the assessment planning process if the original scope is determined to be inadequate.

<u>Determine Assessment Type and Technique</u> – Based on the assessment scope, the determination of the need for a programmatic, facility, or operations/activity based assessment should be made. This determination can be made based on the level of concern, the complexity of associated issues, and on documented trends in performance. Once the type of assessment to be utilized is determined, then the most appropriate

technique can be selected. Additionally, a determination of whether a team assessment or individual assessment should be made based on the extent of the assessment.

Pre-assessment Information Gathering – Assessors will need to gather initial pre-assessment data and evaluate it before they can adequately prepare an assessment plan.

This background and programmatic research should be used by assessment personnel to establish the criteria, performance expectations and indicators which will be used during the assessment. The document review is conducted to :

- Gain familiarity with applicable source documents; and,
- Identify performance objectives, criteria, and expectations concerning facility and/or contractor mission activities in the assessment areas.

Develop the Assessment Plan – The assessment plan is a written and approved document which provides the detailed strategy for preparing for and executing the assessment.

The plan should be developed with the knowledge that a major portion of the actual field work time will be spent in following up on leads developed during the initial planning phase of the assessment. Emphasis should be placed on the identification of repetitive or chronic performance problems, events, or potential programmatic deficiencies. Routine assessments may utilize a standard assessment plan which is approved for a specific performance period and location.

Performance objectives and criteria definition development – Specific performance objectives and criteria are required for each assessment performed. These documented "targets" are part of the performance measuring tools (i.e., performance measures and associated metrics) which are used to measure the performance of the contractor. Specific criteria should be established by which each of the assessment objectives will be evaluated. It is essential that all performance objectives and associated criteria be tied directly to a documented requirement, contract item, or expectation either performance or compliance based. Performance objectives and criteria can be developed from the contract, from approved standards, and other documented and approved sources.

Identify deliverable(s) – The plan shall include the assessor's assessment expectations and a schedule with dates for delivery of draft and final reports.

Schedule development – One of the goals of the scheduling process is to minimize the disruption of facility, task, or process operations. For team assessments and more complex non-team assessments, coordinate with the assessed organization to develop a mutually workable schedule. The schedule may be dynamic once the assessment begins. It must be kept current and changes to it must be provided to all participants as they occur. Included in the schedule are activities such as:

- Assessment notification;

- Assessment entrance meeting;
- Document review;
- Conduct interviews;
- Activity and operations surveillances;
- Drills and simulations;
- Assessor training (radiation worker, procedures, facility, access, etc.);
- Deliverables;
- Assessment report, draft and final, issue dates; and,
- Exit interview.

b. ***Using an appropriate level of coverage, conduct an evaluation of contractor compliance with the requirements of the selected technical standards. During this evaluation, demonstrate the ability to properly conduct interviews, observations, and document reviews.***

Assessment Techniques and Tools – DOE assessment teams are expected to use various assessment tools in determining the performance of the contractor. Use is dependent upon the type of assessment, complexity of the areas being assessed, and other factors. All facility security, safety, and radiological protection requirements must be followed at all times regardless of which technique is utilized. These techniques and tools include:

- Document Reviews – Review of pertinent facility, program, project or activity documentation is conducted prior to, as well as in concert with other assessment activities. An objective review of facility records will assist the assessor in evaluating facility compliance and will provide structured evidence of facility and personnel performance; and,
- Personnel Interviews – An excellent source of assessment information is the interview of responsible facility personnel. Since information obtained from interviews should be treated only as a potential lead or a problem and not a conclusion, interviews are most effective when scheduled early in the assessment process. Early interviews will allow the assessment team time to explore the validity of concerns expressed by personnel and will also provide the opportunity for follow-up interviews should further clarification be required

The following guidelines should be considered when performing personnel interviews:

- Prepare for interviewing personnel by making a list of topics in advance to ensure that essential items are covered;
- Select a suitable location for the interview. Consideration should be given to the comfort of the personnel interviewed;
- Interviewees tend to respond better in a one on one informal basis;
- The interviewer should have a list of questions or topics to be covered. It is essential when conducting interviews to not lead the interviewee responses. On some occasions, it may be necessary to ask leading question in order to draw the

interviewee into the conversation. However, the interviewer should never ask the interviewee to concur with a conclusion that has already been reached; and,

- The interviewer must allow sufficient flexibility for the interviewee to cover desired topics, concerns and recommendations. Over control will result in the interviewee feeling constrained and may also result in negative feedback to other potential interviewees.

c. ***Given data from an evaluation, analyze the results of the evaluation to determine contractor compliance or noncompliance with the requirements.***

Perform assessment

- Conduct interviews
- Perform document reviews
- Perform facility and process walkdowns
- Observe operations and activities
- Document results

d. ***Given the results from an analysis of contractor compliance or noncompliance, document and communicate the results to contractor and Department line management.***

Developing and Issuing the Assessment Report – Formal assessment reports provide documented evidence of an assessment. The report is the document that the customer will use to determine corrective and follow-up actions. It must be clear, concise and to the point. Careful analysis of data collected during assessment activities must be accomplished in order to arrive at a meaningful determination of contractor performance. Conclusions will be provided and augmented by any new information or management guidance in the final phase of evaluation.

- Assessment Report Format – A conventional report format should be utilized by DOE personnel to communicate all assessment activities and results. Conventions for reporting are established at each site. The depth of documentation provided with each assessment is dependent upon the goals of that assessment.
- Review for Factual Accuracy – Prior to issuing a final formal assessment report, a draft of the assessment report should be provided to pertinent DOE and contractor management personnel to review for factual accuracy. Any items of contention between the assessor or assessment team and contractor management should be brought to the immediate attention of appropriate DOE management.
- Report Issuance – Following resolution of comments, assessment reports can be provided to the Contracting Officer Representative for transmittal to the appropriate contractor organization for their consideration and attention in accordance with the procedures and processes established at each specific site.

2.6 Civil/structural engineering personnel shall demonstrate a familiarity level knowledge of the architectural engineering requirements outlined in the following documents as applicable to the review of design specifications for Department of Energy (DOE) facilities:

- Americans with Disabilities Act (ADA);
- General Services Administration (GSA) Space Requirements; and
- Life Safety Codes.

NOTE

Each of the documents, laws, or regulations listed above, given the specialized nature of construction activities and the application of traditional civil/structural engineering disciplines to Department of Energy Facilities serve as MINIMUM guidelines. Applicable DOE Orders, Regulations and Directives will always provide a much more rigorous discipline to which Construction/Civil/Structural engineering personnel must adhere. The DOE Order(s) which is most applicable to each of these enactment's is DOE GENERAL DESIGN ORDER 6430.1A and 1B.

Supporting Knowledge and/or Skills

a. Discuss the basics for the design Codes related to the Americans with Disabilities Act as they pertain to civil/structural engineering.

Americans with Disabilities Act (ADA), enacted on July 26, 1990, provides comprehensive civil rights protections to individuals with disabilities in the areas of employment (title I), state and local government services (title II), public accommodations and commercial facilities (title III), and telecommunications (title IV). Both the Department of Justice (DOJ) and Department of Transportation (DOT), in adopting standards of new construction and alterations of places of public accommodation and commercial facilities covered by title III and public transportation facilities covered by title II of the ADA, have issued implementing rules that incorporates the Americans with Disabilities Act Accessibility Guidelines (ADAAG), developed by the Access Board.

1-1 Title

1-1.1 Americans with Disabilities Act (ADA) of 1990 (Public Law 101-336)

1-2 Purpose

1-2.1 Provide a clear and comprehensive national mandate for the elimination of discrimination against individuals with disabilities.

1-2.2 Provide clear, strong, consistent, enforceable standards addressing discrimination against individuals with disabilities.

1-2.3 Ensure that the Federal Government plays a central role in enforcing the standards established in this Act on behalf of individuals with disabilities.

1-2.4 Invoke the sweep of congressional authority, including the power to enforce the fourteenth amendment and to regulate commerce, in order to address the major areas of discrimination faced day-to-day by people with disabilities.

1-3 Difference between ADA, ADA regulations, and ADAAG

1-3.1 The ADA is a law, passed by Congress and signed by the President in July 1990, that prohibits discrimination on the basis of disability. To effect this prohibition, the statute required certain designated federal agencies to develop implementing regulations, the first of which were promulgated in July of 1991. This rulemaking continues today. The regulators detail a wide range of administrative and procedural requirements, including compliance with design and construction standards; those standards are expressed in the Americans with Disabilities Act Accessibility Guidelines: ADAAG.

1-4 How the ADAAG fits into the ADA regulations

1-4.1 The DOJ and DOT rules describe all of the ADA obligations of covered entities arising from titles II and III of the Act. ADAAG affects only new construction and alterations undertaken by entities covered by the Act establishing minimum requirements for accessibility in buildings and facilities and transportation vehicles subject to the regulations. When adopted by the DOJ and DOT, the Access Board guidelines became the standards for accessible design under title III (title II entities may elect either ADAAG or Uniform Federal Accessibility Standards ((UFAS) until the Board completes title II rulemaking now underway).

1-4.2 Regulations implementing the general provisions of titles II and III of the ADA -- including those that cover buildings and facilities -- were published in the Federal Register (FR) on July 26, 1991 in three parts (the Part designations are FR divisions only and do not relate to titles of the statute):

1-4.3 Part II/Architectural and Transportation Barriers Compliance Board/36 CFR 1191 Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities; Final Guidelines (this is ADAAG);

1-4.4 Part III/Department of Justice/Office of Attorney General/28 CFR Part 36/Nondiscrimination by Public Accommodations and in Commercial Facilities; Final rule (this is title III regulation; subpart C contains requirements for existing facilities; subpart D covers new construction and alterations; ADAAG is incorporated a Appendix A), and

1-4.5 Part IV Department of Justice/Office of Attorney General/28 CFR Part 35/Nondiscrimination on the Basis of Disability in State and Local Government Services; Final Rule (this is the title II regulation; subpart D contains requirements for existing facilities and new construction and alterations).

1-5 How ADAAG was developed

1-5.1 The responsibility to supplement existing accessibility guidelines for application to titles II and III was assigned to the Architectural and Transportation Barriers Compliance Board (The Access Board). A notice of Proposed Rulemaking (NPRM), published in the Federal Register on January 22, 1991, contained the proposed documents, the ADA Accessibility Guidelines (ADAAG), modeled on the format and technical specifications of the American National Standards Institute (ANSI) --ANSI A117.1 - 1980 and 1986 with scoping based on that required by the existing UFAS standard.

1-6 Department of Energy (DOE) Order 6430.1A, General Design Criteria

1-6.1 PURPOSE. To provide general design criteria (GDC) for use in the acquisition of the Department's facilities and to establish responsibilities and authorities for the development and maintenance of these criteria.

1-6.2 SCOPE. The provisions of this Order apply to all Departmental Elements except as otherwise provided by statute or by specific delegation of authority from the Secretary of Energy, and all contractors and subcontractors performing work for the Department whose contract may involve planning, design, or facility acquisitions. This includes DOE-owned, -leased, or -controlled sites where Federal funds are used totally or in part, except where otherwise authorized by separate statute or where specific exemptions are granted by the Secretary or designee.

1-6.3 APPLICABILITY.

a. The GDC provided by this Order shall be applied to all facilities which shall be reported on in the Department's Real Property Inventory System (RPIS), or which shall be reported on in the General Services Administration's annual "Summary Report of Real Property Owned by the United States Throughout the World."

b. The GDC provided by this Order are not intended to provide complete coverage for the diverse facilities by type and complexity that are needed to support the varied Departmental program-mission requirements.

Specific project criteria and/or specifications need to be developed to satisfy the needs for a particular facility, incorporating applicable requirements of these general design criteria and supplemented with required criteria from applicable *Code*s and standards.

c. It is recognized that many of the Departmental organizations having responsibilities for facility planning, design, and construction may establish and apply more comprehensive criteria to satisfy the particular program mission or operating requirements. There is no intent that the GDC take precedence over such other criteria, where those criteria meet or exceed the GDC requirements. Where there exists a conflict between those criteria and the GDC provided by this Order, however, the GDC governs.

1-6.4 POLICY AND OBJECTIVES.

a. Policy. It is DOE policy that:

(1) Professional architectural and engineering principles and practices be applied to the planning, design, construction, alterations, and/or acquisition of the Department's facilities.

(2) All Departmental facilities will comply with the Federal and Departmental regulations for energy conservation and use of renewable energy.

(3) The planning, design and construction of the Department's facilities will be performed in a manner that will satisfy all applicable Executive Orders, Federal laws, and regulations. While the Department is not required to comply with state and local building *Code*s, laws, and ordinance; the planning, design, and construction processes should accommodate them to the extent consistent with the accomplishment of the Department's mission.

(4) All Department facilities are to be designed and constructed to be reasonable and adequate for their intended purpose and consistent with health, safety, security, and environmental protection requirements.

b. Objectives.

(1) To provide GDC that ensures implementation of the Department's policy covering:

(a) The basic architectural and engineering disciplines.

(b) Certain types of the Department's known facility requirements.

(c) Specialized requirements based on programmatic and operating experience.

(2) To establish authorities, responsibilities, and procedures that ensure timely development and maintenance of the GDC.

b. Identify and discuss the General Services Administration space requirements.

General Service Administration (GSA) space requirements are outlined in the Code of Federal Regulations (CFR) under two documents to which DOE employees must be attentive and responsive to insure that all portions of the applicable code are being adhered to. The two codes which have direct impact on DOE facilities are: Public Contracts and Property Management, CFR 41, Chapter 101, and Department of Energy Property Management Regulations, CFR 41, Chapter 109.

However, DOE Order GENERAL DESIGN CRITERIA, 6430.1A, and B still control with the above referenced documents merely serving as MINIMUM guidelines.

c. Identify and discuss the life safety codes.

Life Safety Code: The *Life Safety Code* has its origin in the work of the Committee on Safety to Life of the National Fire Protection Association first appointed in 1913. For the first few years of its existence the committee devoted its attention to the study of notable fires involving loss of life and to analyzing the causes of that loss of life. This work led to the preparation of standards for the construction of stairways, fire escapes, and similar structures; for fire drills in various occupancies; and for the construction and arrangements of exit facilities for factories, schools, and other occupancies, which form the basis for the present *Code*.

1-1 Title

1-1.1 The *Code* shall be known as the *Life Safety Code* (In 1966 the title was changed from *Building Exits Code* to *Life Safety Code*)

1-2 Purpose

1-2.1 The purpose of the *Code* is to establish minimum requirements that will provide a reasonable degree of safety from fire in buildings and structures. (The *Code* reflects what should be considered MINIMUM requirements that endeavor to insure safety of occupants from fires and similar emergencies.)

1-2.2 The *Code* endeavors to avoid requirements that might involve unreasonable hardships or unnecessary inconvenience or interference with the normal use and occupancy of a building, but insists on compliance with minimum standards for fire safety consistent with the public interest.

1-3 Scope

1-3.1 The *Code* addresses life safety from fire and similar emergencies.

1-3.2 The *Code* addresses those construction, protection, and occupancy features necessary to minimize danger to life from fire, smoke, fumes, or panic.

1-3.3 The *Code* identifies the minimum criteria for the design of egress facilities so as to permit prompt escape of occupants from buildings or, where desirable, into safe areas within the building.

1-3.4 The *Code* recognizes that life safety is more than a matter of egress and, accordingly, deals with other considerations that are essential to life safety.

1-3.5 Where in fixed locations and occupied as buildings, vehicles, vessels, or other mobile structures shall be treated as buildings.

1-3.6 The *Code* does not attempt to address those general fire prevention or building construction features that are normally a function of fire prevention or building *Code*s.

1-3.7 The prevention of accidental personal injuries during the course of normal occupancy of buildings, personal injuries incurred by an individuals own negligence, and the preservation of property from loss by fire have not been considered as the basis for any of the provisions of the *Code*.

1-4 Objective

1-4.1 The objective of the *Code* is to provide a reasonable level of safety by reducing the probability of injury and loss of life from the effects of fire and other emergencies having the potential for similar consequences with due consideration for functional requirements. This objective is accomplished within the context of the physical facilities, type of activities undertaken, the provisions for the capabilities of the staff, and the needs of the occupants. The level of safety is defined by the combination of prevention, egress, and other features enumerated in specific or individual occupancy portions of the *Code*.

The level of life safety is defined through the requirements directed at the:

a. Prevention of ignition.
b. Detection of fire.
c. Control of fire development.
d. Confinement of the effects of the fire.
e. Extinguishment of fire.
f. Provision of refuge and/or evacuation facilities.
g. Staff reaction.
h. Provision of firesafety information to occupants.

1-5 Application

1-5.1 The *Code* applies to both new construction and existing buildings. There are specific provisions for existing buildings that may differ from those for new construction.

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(3) The planning, design and construction of the Department's facilities will be performed in a manner that will satisfy all applicable Executive Orders, Federal laws, and regulations. While the Department is not required to comply with state and local building codes, laws, and ordinance, the planning, design, and construction processes should accommodate them to the extent consistent with the accomplishment of the Department's mission.

(4) All Department facilities are to be designed and constructed to be reasonable and adequate for their intended purpose and consistent with health, safety, security, and environmental protection requirements.

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4.6 Civil/structural engineering personnel shall demonstrate the ability to act as the Department's subject matter experts for civil/structural engineering activities by routinely interacting with Federal, State, local and public stakeholder representatives during the oversight and management of civil/structural engineering programs.

a. Discuss the roles and responsibilities of site and/or community advisory boards on civil/structural engineering issues as described in

- Public Law 92-463, October 6, 1972, and subsequent amendments, Federal Advisory Committee Act.

The primary charter of the Citizen Advisory Board (CAB) is to provide informed recommendations, ideas, and advice to DOE, EPA and local health departments on policy and technical issues and decisions related to cleanup, waste management and associated activities. The function of the CAB is an advisory function, only. Information on projects should be sent to the CAB early in the decision making process, and the CAB given the opportunity to be provide recommendations prior to final decisions being made. Concerns and comments of the CAB and stakeholder should be reflected in the overall decision making process at federal facilities.

b. Given data, discuss the Department of Energy's official position on three civil/structural engineering issues that impact one or more of the above segments (Federal, State, local, public stakeholders).

This is a demonstration skill.

It is the responsibility of a DOE facility Communication Department to manage and maintain the official position of the DOE on a specific issue, and to provide a consistent message to its stakeholders. The Communication Department can also assist with the appropriate level of public involvement for a specific project or issues.

c. Discuss the Freedom of Information Act and its impact on Department civil/structural engineering programs. State all security precautions to be taken with regard to relevant programs and the Freedom of Information Act.

It is the policy of the DOE to make information publicly available to the fullest extent possible, except where this information is exempt from disclosure under the FOI, 5 U.S.C. 552 (Public Law 90-23, as amended) or under other applicable statutes (the Privacy Act of 1974, 5 U.S.C. [a]). Officers and employees of the DOE may furnish to the public informally and without compliance with the procedures of this Order, information and records of types which are customarily furnished to the public in the regular performance of their duties. There is no obligation on the part of the DOE to compile or create a record solely for the purpose of satisfying a request for records.

Where a contract with the DOE stipulates that any documents relating to work under the contract shall be the property of the Government, such records shall be considered to be agency records and subject to disclosure under the FOIA. However, if a contract does not make such specific provisions, no DOE contractor records shall be considered to be agency records unless and until such time that the DOE acquires possession of the particular contractor documents.

For specific roles and responsibilities, see DOE Order 1700.1. Roles and responsibilities described with regard to the FOIA include those for the Direction of Administrative and Human Resources Management, Director of Administrative Services, the General Counsel, Heads of Field Elements, Freedom of Information Officers, and Authorizing Officials. Personnel not fulfilling any of these roles should forward any requests to the appropriate DOE official. For a FOIA request, records are to be promptly identified and reviewed by an Authorizing Official. The Authorizing Official will consult and obtain concurrence of the General Counsel prior to any determination to deny access to records.

Protection of classified or UNCI information and restricted access to classified materials is required at many facilities. If there is any potential that information in the project documentation is classified, then classification guidance should be requested or documents reviewed by an authorized classifier. DOE Order 5632.1C, Protection and Control of Safeguards and Security Interests, ands DOE M 5632.1C-1, Manual for Protection and Control of Safeguards and Security Interests require a security plan for projects considered to be a concern.

d. Under simulated conditions, demonstrate skill in dealing with the public and other stakeholders and when dealing with difficult people.

This is a demonstration skill.

Participants in a group may be positive, supportive and contributory; however, occasionally a participant may be negative, obstructive, or non-contributory during a public meeting. Situations may be defused up front by discussing the focus and purpose for the meeting, and inviting and encouraging participation.

Other techniques for handling resistive behavior during the meeting, include:

- Restate questions, rephrase and summarize if someone is excessively talking;
- Seek participation from others in the group if someone is dominating;
- Restating the focus and purpose of the meeting if someone is getting off track;
- Breaking into smaller groups if getting little participation;
- Do allow some venting if someone disagrees; and
- Keep calm and do not get angry.

e. ***Given civil/structural engineering-related program data, identify those portions of the data which are required to be communicated to external organizations and discuss any potential impacts on Department programs.***

This is a demonstration requirement.

The following activities require stakeholder involvement:

- Activities and project with potential risk or impact to the human health or the environment;
- Any activity requiring regulatory oversight by another local, state, or federal agency; and
- Any activities where stakeholder buy-in would benefit the project moving forward and the overall credibility of the agency (resolve conflict or controversy, support funding, etc.).

The following environmental regulations require communication with external agencies, and are commonly related to agency projects:

Laws and Orders Commonly Related to Agency Projects		
Environmental Laws and Executive Orders	**Oversight Agency**	**Concern/Action**
Endangered Species Act	U.S. Fish and Wildlife National Marine Fisheries Service	Protection of threatened and endangered species/biological assessments and opinions
Fish and Wildlife Coordination Act	U.S. Fish and Wildlife	impacts to fish and wildlife/consult, mitigation
Coastal Zone Management Act	National Oceanic and Atmospheric Agency	impacts on coastal zone/findings of consistency with State Management Plans
National Historic Preservation Act	State Historic Preservation Office	preservation of prehistoric and historic sites/consultation
Native American Graves Protection and Repatriation Act	State Historic Preservation Officer Affected Native American Tribes	protection to gravesites, human remains, and funerary objects/consultation with Native American Groups and SHPO
Clean Air Act (Conformity Rule)	Environmental Protection Agency (State Primacy)	Air pollution/permits, inspection, reports
Federal Water Pollution Control Act (Clean Water Act)	Environmental Protection Agency (State Primacy)	water pollution/ National Pollution Discharge Elimination System (NPDES) permit (EPA) and Section 404 permit-Dredge/fill (Corp of Engineers) inspections, reports
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	Environmental Protection Agency (State Primacy)	past disposal of waste/taxing, reporting, liabilities

Resource Conservation and Recovery Act (RCRA)	Environmental Protection Agency (State Primacy)	Hazardous and Nonhazardous waste management/permits, manifests, inspections, reports

Additional regulations and executive orders that involve consultation and/or stakeholder involvement include:

- Executive Order for Environmental Justice-affected minority and low income groups;
- American Indian Religious Freedom Act-affected Native American groups;
- Prime and Unique Agricultural Lands-Department of Agriculture; and
- Local regional, state land use and zoning commissions.

Proper and adequate environmental planning is critical to the project management process. For any given project, a large number of environmental requirements may be applicable. Environmental issues, if not given adequate consideration, can create significant difficulty in maintaining established project baselines.

f. Using techniques applicable to the situation, communicate with Headquarters Program Office representative(s); the Department's Legal representatives; contractor; State; and local officials.

This is a demonstration requirement.

The following types of information should be communicated to Headquarters Program Office representatives, Department of Energy Legal representatives, contractors, state, and local officials:

- information related to the officials oversight role (i.e., potential environmental impacts, land use.);
- potential problems with public stakeholders;
- potent for demonstrations;
- problem or an emergency associated with a project;
- stakeholder issues associated with a project, prior to a visit; and
- emphasis should be on early meaningful involvement, or as soon as an issue has arisen-no secrets or surprises.

g. Given actual reports from the Defense Nuclear Facilities Safety Board (DNFSB), the Government Accounting Office (GAO), Tiger Teams, or any other entity external to civil/structural engineering, report on the applicability of these reports and any resulting implementation plans to Department civil/structural engineering programs.

This is a demonstration skill.

In this exercise, review the document and denote all pertinent civil and structural engineering issues, including, but not limited to:

- building integrity;
- building size;
- designs;
- layouts;
- building materials;
- built environment;
- utility systems;
- building access;
- waste water;
- potable water;
- slope stability;
- soil properties;
- building codes;
- survey, grading, drainage;
- weather and natural hazards; and
- runoff.